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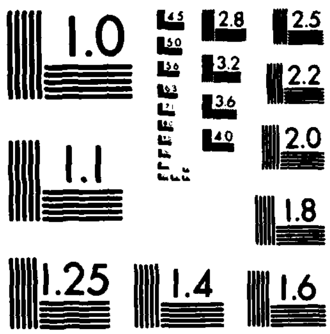

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THE INFLUENCE OF TURBULENCE AND DECK SECTION GEOMETRY ON THE AEROELASTIC BEHAVIOUR OF A CABLE-STAYED BRIDGE MODEL

by

S.J. Zan, H. Yamada, H. Tanaka
National Aeronautical Establishment

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THE INFLUENCE OF TURBULENCE AND DECK SECTION GEOMETRY ON THE AEROELASTIC BEHAVIOUR OF A CABLE–STAYED BRIDGE MODEL

LES EFFECTS DE LA TURBULENCE ET DE LA GÉOMÉTRIE DE SECTIONS DE TABLIER SUR LE COMPORTEMENT AÉROÉLASTIQUE D'UNE MAQUETTE DE PONT À HAUBANS

by/par

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National Aeronautical Establishment

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SUMMARY

The Low Speed Aerodynamics Laboratory of the National Aeronautical Establishment (NAE) has conducted research on bridge aerodynamics ~~for two decades, during~~ has made which time substantial progress ~~has~~ been made ~~here and at other laboratories~~ in predicting prototype behaviour based on various scale model tests performed in wind tunnels. In spite of these efforts, there still remain important effects that are not completely understood; one of which is the effect of atmospheric turbulence on the wind-induced behaviour of the bridge.

A recent consideration for bridge aerodynamics research is the trend in North America and Japan to erect cable-stayed crossings. These structures, by nature, possess complex dynamic characteristics, which lead to difficulties in determining the responses to aerodynamic loading.

What is contained in this report are the results of a full aeroelastic model test of a cable-stayed bridge at a geometric scale of 1:75. Nine deck section configurations were tested in three different flows; two of which were properly scaled atmospheric turbulence, and the third being smooth flow. The experiments were performed in ~~the NAE~~ a 9 m x 9 m wind tunnel. (Canada)

Sommaire

Le Laboratoire aérodynamique des faibles vitesses de l'Établissement aéronautique national (ÉAN) réalise des études sur l'aérodynamique des ponts depuis vingt ans. Au cours de cette période des progrès importants ont été accomplis ici-même ainsi qu'à d'autres laboratoires dans le but de prédire le comportement de prototypes de ponts. Ces comportements ont été déterminés grâce à des essais dans des souffleries sur différentes maquettes. Malgré ces efforts, d'importants comportements ne sont pas encore complètement compris, tel l'effet de la turbulence atmosphérique sur un pont balayé par le vent.

Une des récentes considérations vis-à-vis la recherche aérodynamique des ponts est la tendance en Amérique du Nord et au Japon d'ériger des ponts à haubans. Du fait de leur nature, ces structures ont des caractéristiques *dynamiques complexes* et par conséquent entraînment des difficultés à déterminer les réactions aux charges aérodynamiques.

Le présent rapport communique les résultats d'une maquette d'essai aéroélastique complet d'un pont à haubans d'une échelle géometrique de 1:75. Neuf configurations de sections de tablier ont été mises à l'essai sous trois écoulements différents. Deux de ces écoulements étaient des turbulences atmosphériques d'échelle convenable tandis que le troisième était laminaire. Les expériences ont été effectuées dans la soufflerie de 9 m x 9 m de l'É.A.N.

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (Cont'd)

LIST OF SYMBOLS

f	- frequency of vibration
f_o	- frequency of first torsion mode
f_z	- frequency of first bending mode
k	- constant in equation 4.1
ℓ	- length of bridge
m	- mass per unit length of bridge deck
n	- frequency
u	- component of wind velocity normal to bridge axis
v	- component of wind velocity along bridge axis
w	- vertical component of wind velocity
x	- direction normal to bridge axis
y	- span wise direction
z	- vertical response of bridge; vertical direction
$\hat{z}$	- peak vertical response of bridge deck
B	- bridge deck chord
D	- bridge depth (girder plus traffic barrier)
EA	- axial stiffness
EC_w	- warping rigidity
EI	- vertical bending rigidity
EI_ℓ	- lateral bending rigidity
GK	- torsional rigidity
L_1, L_2	- turbulence length scales
$S_u(n)$	- power spectral density of u component of wind velocity
$S_w(n)$	- power spectral density of w component of wind velocity
U	- mean wind speed in x direction
U_r	- reduced velocity = U/f_zB
α	- exponent in equation 4.1
θ	- mass moment of inertia per unit length of bridge deck
λ_L	- length scaling factor = 1/75

λ_T - time scaling factor = 1/15

λ_ρ - density scaling factor = 1

σ_u - root mean square value of fluctuating component of velocity in x direction

σ_w - root mean square value of fluctuating component of velocity in z direction

$\hat{\theta}$ - peak torsional response of the bridge deck

1.0 INTRODUCTION

This report presents the results of wind tunnel tests of a 1:75 scale full aeroelastic model of a cable-stayed bridge. Since the collapse of the Tacoma Narrows Bridge in 1940, there have been many wind tunnel studies of the wind-induced response of bridge road decks. However, persistent questions remain in the design of major bridges against wind action. Consequently, it is still standard practice to wind tunnel test the design of any new prototype. At the present time, the best procedure for predicting the response of bridges to natural wind is to immerse a structurally simulated model in a turbulent shear layer that simulates as closely as possible the conditions at the site of the prototype structure. However, this procedure has been successfully applied to only a small number of bridges in the past, because of technical difficulties, financial constraints and probably unavailability of experimental facilities large enough to accommodate full bridge models (Refs. 1,2,3,4,5).

An alternative approach to the full model test is the conventional sectional model wind tunnel test of the bridge, which has been widely practiced for years. This method can well simulate the structural geometry of the bridge, but the simulation of wind turbulence has been traditionally neglected. Testing of sectional models in smooth flow in aeronautical wind tunnels usually provides conservative estimates of the wind-induced responses expected for a girder cross-section (Ref. 6).

There are still two major problems with sectional model testing. First, advances in cost-effective design of bridges, as a result of competitive bidding between steel and concrete road deck configurations in recent years, have produced deck sections bordering on acceptability from an aerodynamic standpoint. The result is a strong impetus to determine the extent of the aerodynamic margin provided by the sectional model studies. Secondly, the prototype buffeting response to wind turbulence has to be estimated by other means. The question that arises from this situation is: Can the sectional model test

provide all of the necessary information for the bridge designers, including the effects of turbulence? There have been several new approaches attempting to open avenues to this question (Ref. 7,8,9) but it still remains an important one. The purpose of the present research into bridge aerodynamics at the National Aeronautical Establishment (NAE) is largely to investigate this key issue.

Another approach sometimes undertaken for the study of bridge aerodynamics is the use of a so-called "taut strip" model with relatively better simulated flow conditions than the sectional model study. This is not a full aeroelastic model test, but is a method which could be described as a three-dimensional sectional model test. The usefulness of this type of model has been demonstrated for the analysis of some suspension bridges (Ref. 10,11); however care should be taken when it is applied to cable-stayed bridges, since the idea of the taut-strip model was originally developed with the concept of the dynamics of suspension bridges (Ref. 12) in mind. For the case of suspension bridges, the vibration mode shapes can often be approximately constructed by the combination of half sine-wave shapes, because the mechanical characteristics of the whole bridge deck are more or less equivalent to a simply supported beam with the axial force in the longitudinal direction. Cable-stayed bridges, on the other hand, tend to exhibit very different vibration modes since the bridge behaves basically as a continuous beam on a large number of elastic supports. Hence the simulation of bridge vibration modes by an ordinary taut-strip model becomes more difficult. Moreover, a large number of complex vibration modes tend to be crowded with only small differences in natural frequency for the case of cable-stayed bridges, and consequently the coupling and interaction between several modes can also have appreciable significance on the dynamic behavior of the structure (Ref. 13). This fact requires careful attention since the cable-stayed bridge has recently emerged as a popular alternative to the suspension bridge for the intermediate and even long spans.

What is reported here are the results of the testing of a full aeroelastic model of the steel version of the Quincy Bridge over the

Mississippi River. Previous wind tunnel testing by the NAE (Ref. 14) was performed using a sectional model. In addition to the tests on the Quincy section, the model was tested with various other fundamental configurations of road deck systems frequently employed for cable-stayed bridges. A novel model design permitted simple interchanges of the various deck sections, without affecting the structural dynamic characterisitics of the model. A series of sectional model tests with these bridge sections is being carried out presently at the same model scale, although the results from the sectional model tests will not be discussed here.

2.0 AEROELASTIC MODEL

2.1 Physical Properties

It was considered desirable that the aeroelastic bridge model simulate a typical contemporary cable-stayed bridge. The prototype bridge selected as a basic structure for this study is the crossing over the Misissippi River at Quincy, Illinois designed by Modjeski and Masters. At the time of writing, the erection of this bridge is underway. The choice of this prototype bridge was made partly because the Quincy bridge is a typical medium-span cable-stayed bridge in North America, and also because study of the wind-resistant design of this bridge has been carried out at the NAE Low Speed Aerodynamics Laboratory for the past few years. Modifications to the original Quincy deck section were made as a result of this testing (Ref. 14).

The mass and stiffness distribution as well as the geometrical features of the bridge were modelled with the length scale of 1:75. The physical properties of the Quincy Bridge and the aeroelastic model for the present study are compared in Table 1. The overall dimensions of the model are given in Figure 1. Figure 2 shows the model installed in the wind tunnel.

TABLE 1 **Physical Properties of Quincy Bridge and Aeroelastic Model**

Physical Properties	Quincy Bridge	Aeroelastic Model
Mass per unit length of of bridge deck (m)	15.16×10^3 kg/m (316.6 slug/ft)	2.77 kg/m (0.0578 slug/ft)
Mass moment of inertia per unit length of bridge deck (θ)	(315.7×10^3 kg m^2/m) (71.27×10^3 slug ft^2/ft)	(10.7×10^{-3} kg m^2/m) (2.40×10^{-3} slug ft^2/ft)
Vertical bending rigidity (EI)	46.43×10^9 N m^2 * (112.3×10^9 lb ft^2)	59.9 N m^2 (145 lb ft^2)
Lateral bending rigidity (EI_ℓ)	0.1948×10^9 N m^2 * (0.4711×10^9 lb ft^2)	39.9 N m^2 ** (96.4 lb ft^2)
Axial rigidity (EA)	73.94×10^9 N * (16.62×10^9 lb)	3.16×10^6 N ** (710×10^3 lb)
Torsional rigidity (GK)	770×10^6 N m^2 *** (1.862×10^9 lb ft^2)	1.15 N m^2 **** (2.77 lb ft^2)

Notes:

* of two main girders

** not simulated

*** assuming a rigid connection between the main girders and the concrete road deck

**** the equivalent torsional stiffness $GK_{eq.} = GK + EC_w \left(\frac{\pi}{2\ell}\right)^2$ is simulated using the estimated warping rigidity EC_w, approximately 4.2×10^{12} N m^4 (110×10^{12} lb ft^4) at prototype scale.

The length scale choice of $\lambda_L = 1/75$ was determined from the total length of the bridge and the available space of the wind tunnel test section. The time scale was chosen to be $\lambda_T = 1/15$ for the convenience of the design of cables. This scaling factor is smaller than the time scaling factor

$$(\lambda_T)_F = \sqrt{\lambda_L} = 1/8.66$$

required from the Froude Number similitude. The Froude Number similitude was relaxed here since the dynamic behaviour of the bridge model is unlikely to be influenced by gravity forces. The model scaling factors are summarized in Table 2.

TABLE 2 Model Scaling Factors

Properties	Model scale value / Full scale value
Length	$\lambda_L = 1.33\text{x}10^{-2}$ (1:75)
Time	$\lambda_T = 6.67\text{x}10^{-2}$ (1:15)
Velocity	$\lambda_V = \lambda_L/\lambda_T = 0.200$ (1:5)
Acceleration	$\lambda_a = \lambda_L/\lambda_T^2 = 3.00$
Density	$\lambda_\rho = 1$
Mass	$\lambda_\mu = \lambda_L^3\lambda_\rho = 2.37 \times 10^{-6}$
Mass moment of inertia	$\lambda_\theta = \lambda_\mu\lambda_L^2 = 4.21 \times 10^{-10}$
Force	$\lambda_F = \lambda_\mu\lambda_a = 7.11 \times 10^{-6}$
Moment	$\lambda_M = \lambda_F\lambda_L = 9.48 \times 10^{-8}$
Bending rigidity	$\lambda_{EI} = \lambda_F\lambda_L^2 = 1.26 \times 10^{-9}$
Torsional rigidity	$\lambda_{GK} = \lambda_F\lambda_L^2 = 1.26 \times 10^{-9}$
Axial rigidity	$\lambda_{EA} = \lambda_F = 7.11 \times 10^{-6}$

As is evident from Table 2, the model dead load acting through the cable system is decided only by the length scale. This causes a slight problem for the equilibrium of cable tensions and the bridge weight since the axial rigidity EA of the cable is influenced by the distortion of Froude similitude. In order to avoid this inconsistency, the simulation of cable tension alone was based on the Froude similitude, thus the scaling factor for the cable tension, F_c, is given by

$$\lambda_{F_c} = \lambda_L^3 = 2.37 \times 10^{-6}$$

The arrangement of cables and their axial rigidity and introduced tension are summarized in Figure 3. The cable tension was determined from the natural frequency of each cable. Tuning was accomplished by the use of a small peg installed at the tower anchorage.

2.2 Description of Model

Design details of the model are given in Figures 4-11. The basic mechanical characteristics of the model are provided by the towers, cables and the bridge deck and floor system including two stiffening beams. Bending stiffnesses of the bridge girder in both vertical and lateral directions are assumed to be represented only by these stiffening beams.

The model was wind tunnel tested for the following nine configurations, (Fig. 11a):

1. Original Quincy section
2. Final Quincy section
3. Composite girder section
4. Plate Girder section ($B/D \simeq 4.7$)
5. Plate Girder section with modified edges on the centre span
6. Single box section
7. Single box section with modified edges on the centre span
8. Twin box section
9. Twin box section with modified edges on the centre span

The model is designed in such a way that the change of these various configurations can be made without affecting the basic structural system of stiffening beams and cables. The configuration No. 3 "Composite girder section" somewhat resembles the cross-section of the Annacis Island Bridge, New Westminster, British Columbia, with the approximate length scale of 1:150, except the Jersey traffic barriers are almost double sized.

2.3 Dynamic Characteristics of the Model

Prior to the wind tunnel testing, free vibration tests were carried out to identify the dynamic characteristics of the model. The results are summarized as follows:

Vibration Mode	Frequency (Hz)	Damping ratio (% of critical)
1st Sym. Bending	5.0	0.66
1st Asym. Bending	6.7	0.55
2nd Sym. Bending	10.5	0.60
1st Sym. Torsion	11.9	0.62

3.0 EXPERIMENTAL PROCEDURE

3.1 Wind Simulation

One of the primary objectives of this experiment was to assess the effects of turbulence on the behaviour of bridge road decks. It was decided that the experiment would be performed using three different wind simulations, designated as smooth flow, slightly turbulent flow, and highly turbulent flow. Standard two-dimensional section models are tested in smooth flow, so the series of experiments performed in smooth flow will allow for direct comparison between two dimensional section model response and three dimensional full model response. It is not intended to examine this comparison in the present report.

The full model response in a simulated atmospheric boundary layer should not be different from that of a prototype in the actual atmospheric boundary layer. The atmospheric boundary layer is a turbulent shear flow which can be characterized by three properties for the purposes of wind engineering studies. The three properties are:

(i) the mean wind speed, and its variation with height,

(ii) the turbulence intensity, (defined as the ratio of root mean square velocity to local mean velocity), and its variation with height,

and (iii) the spectra of turbulence, from which the length scales of turbulence can be determined.

For a slender horizontal structure such as a cable-stayed bridge, the variations of mean wind speed and intensity with height do not greatly affect the response of the structure. Furthermore, of the nine length scales L_u^x, L_u^y, L_u^z, L_v^x, L_v^y, L_v^z, L_w^x, L_w^y, and L_w^z, only L_u^x, L_u^y, and L_u^z, have a substantial effect on the response of the structure. In this experiment, the turbulence intensities and length scales of importance were representative of full scale values at deck height.

The effects of turbulence on the behaviour of section models have been examined with the use of grid generated turbulence (Ref. 14). A passive grid serves to correctly model the intensity, but the length scales are generally only a fraction of the bridge chord for a typical section model, whereas full scale values of length scales are up to an order of magnitude greater than the bridge chord. Bearman (Ref. 15) states that the flow characteristics and mean loads on bluff structures are sensitive to the value of turbulence intensity, whereas the length scales are important when considering the response to unsteady (buffeting) loads.

General conclusions on the effects of turbulence on bridge road decks indicate that the presence of turbulence is beneficial, in that the amplitude of response due to vortex shedding is reduced, and

the critical velocity for the onset of torsional instability is raised. These results have been noted for full aeroelastic models in a properly simulated wind layer (Ref. 4), and for section models subject to grid generated turbulence (Ref. 14).

As mentioned, two simulations of the atmospheric boundary layer were used during the experiment. The first simulation was labelled as highly turbulent flow, with a turbulence intensity of about 12% at deck level in the streamwise direction and 6.2% in the vertical direction. This shear layer was produced using the spire technique, which is well described in Reference 16. Figure 12 shows the variation with height of the mean wind speed and turbulence intensity in the free stream direction, which although simulated correctly, is not a requirement. These measurements were made using a TSI single hot film probe.

The non-dimensional power spectra of the u and w components for this simulation are plotted in Figures 13 and 14. Using the Von Karman models for these spectra, the length scales were computed for this simulation. The expressions for the power spectra in non-dimensional form are:

$$\frac{nS_u(n)}{\sigma_u^2} = \frac{4\left(\frac{nL_1}{U}\right)}{\left[1 + 70.78\left(\frac{nL_1}{U}\right)^2\right]^{5/6}} \qquad L_1 = L_u^x \qquad (3.1)$$

$$\frac{nS_w(n)}{\sigma_w^2} = \frac{2\left(\frac{nL_2}{U}\right)\left[1+188.8\left(\frac{nL_2}{U}\right)^2\right]}{\left[1 + 70.78\left(\frac{nL_2}{U}\right)^2\right]^{11/6}} \qquad L_2 = 2L_u^z \qquad (3.2)$$

The values of L_1 and L_2 were computed to be 0.658 m and 0.256 m respectively at model scale. Figure 15 is a plot of Teunnissen's model (Ref.17) for L_1 and L_2 as a function of height, derived from full scale measurements. The values are shown at prototype scale. The agreement

is excellent. It was concluded that the spire generated wind simulation was satisfactory in all respects.

The second turbulent wind simulation was deemed a slightly turbulent flow, simulated using a flow trip on the floor of the tunnel at the entrance to the test section. The flow trip was a standard 2 x 4 building stud mounted such that the 4 inch dimension was normal to the direction of flow. The length of fetch between the trip and the model, about 23 m, allowed the boundary layer to develop to a degree such that the road deck, which was 0.3 m above the floor, was subject to a turbulent shear flow. The top of the shear layer was less than 15 cm above the road deck. The turbulence intensity at deck level in the streamwise direction was 5%, and 2.6% in the vertical direction. A check was made to ensure that the flow at deck level was consistently turbulent.

Figures 16 and 17 are plots of the non-dimensional power spectra of the u and w components of turbulence for the slightly turbulent flow. For these data, the length scales L_1 and L_2 are 0.543 m and 0.140 m. The corresponding values at prototype scale can be found in Figure 15. These length scales were also considered acceptable. Some benefit was derived from locating the road deck in the upper portion of the boundary layer. Since length scales increase with height in a shear layer, more realistic values of L_1 and L_2 could be obtained.

Having been satisfied that the wind simulations were adequate, it was necessary to monitor only the mean wind speed during the actual testing. This was accomplished using a fluidic cross flow velocity sensor (Fig. 18) positioned on the tunnel centerline at a height of 1.57 m above the floor. This device has a linear response for wind speeds ranging from 0 to 13 m/s. For windspeeds above 13 m/s, the wind speed was obtained from the wind tunnel fan speed (RPM). A linear relationship exists between fan speed and wind speed. For smooth flow, the velocity at the sensor height was identical to that at deck level. For slightly turbulent flow, the velocity at deck level was 92% of that

at the sensor level, and for highly turbulent flow, the deck level velocity was 85% of that at the sensor level.

3.2 Model Installation

The bridge model was installed in the 9 m x 9 m wind tunnel at the downstream end of the test section, at the breathers. This wind tunnel has a specially designed wind engineering platform at this location which is free from effects of tunnel shell vibrations. With this platform, it was assured that any model vibrations were due to aerodynamic effects, and not a combination of aerodynamic effects and tunnel vibration, which would have been the case if the model were mounted on the wind tunnel floor. Survey equipment was used to ensure that the two pedestals and two end shoes were positioned at the correct height. The pedestal surfaces were also "levelled" in both the streamwise and cross flow directions. These precautions led to a mean angle of attack of zero degrees, zero minutes at the centre of the deck.

The only disadvantage of the support system was that yawed wind behaviour could not be investigated, since the model could not be yawed and still remain on the pedestals.

Figure 1 shows the locations of the proximity transducers with respect to the model. Two transducers were mounted at the centre of the main span, two at the centre of the side span, and two each at the one-sixth points of the centre span. The transducers were placed 51 mm apart (Fig. 19) and arranged such that the sum of their outputs was proportional to the bending amplitude and the difference between their outputs was proportional to the torsion amplitude.

Upon completion of the installation, it was required that the cables be "tuned" in order that the dynamic behaviour of the model correctly simulate that of a prototype. An initial tuning was performed before the model was transported to the wind tunnel, but it was thought that the final tuning should not be done until the model was mounted in

the wind tunnel. Rather than measuring the cable tensions directly, an alternate technique was employed. The desired values of model tension for each cable were known, and so the frequencies of each cable could be computed using vibrating string theory. Several methods were employed in the attempt to measure the natural frequencies of the cables. In the end, the cables were "plucked", and a sensitive sound level meter (B&K 4133) was used to detect the sound. The signal from this meter was fed to a spectrum analyzer, whereupon the frequencies could be obtained. It was interesting to note that the frequency of a given cable could best be determined by noting the difference between two harmonic peaks, since the harmonics are all integral multiples of the fundamental. In most cases, the peak of the fundamental was buried in low frequency background noise.

Cable tuning was a time consuming iterative procedure since the deck/cables/tower system has strong interactions. During testing, the cable frequencies were checked occasionally, but no significant changes had occured.

3.3 Instrumentation

The eight proximity transducers enabled measurements of bending and torsion amplitudes to be calculated at four stations along the bridge. The calibration of the transducers was checked every morning before the first run of the day. It was found that there was a considerable drift (approximately 5 to 10%) on several channels each morning during the first week of testing. In a few cases recalibration required several hours. These drifts were assumed to be a result of temperature effects since the tunnel is exposed to the outside temperature. There can be a variation of about 15°C between daily minimum and maximum temperatures in the month of September, during which the testing took place. The transducer outputs were very stable during the final two weeks of testing.

The analog outputs from the transducers were low pass filtered

and fed to the data acquisition system (Megadac 2200C). The 3 dB cutoff frequency of the filters was 50 Hz with a roll off of 160 dB per decade. The cross flow velocity sensor output was low pass filtered at 1 Hz, since only the mean value was of interest, and the filtered signal was fed to the data acquisition unit.

The eight channels containing filtered proximity transducer outputs were connected to sample-and-hold modules in the data acquisition unit, which eliminated the skew associated with sequential sampling. The signal from the velocity sensor was not connected to a sample-and-hold module since there was no concern about having the mean velocity skewed with respect to bridge deflection. Data were acquired at 40 Hz per channel, i.e. 360 samples were recorded per second. A typical run consisted of sampling for one minute, which is the equivalent of 15 minutes at prototype scale.

The reduction of data to produce bending and torsion deflections was performed offline using software routines.

4.0 RESULTS

Figures 20 through 24 are plots of the normalized peak bending and torsional response versus reduced wind speed, for the various deck sections. Deflection is taken at the mid span point unless otherwise specified. Actual data points were omitted for clarity; computer listings of the responses are found in Appendix C. The composite girder section is not shown, as no appreciable motion was observed in smooth flow ($U_r \leq 20.4$). This section was also relatively insensitive to buffeting resulting from wind turbulence.

4.1 Vortex Shedding

A vortex shedding induced response was observed only for the Original Quincy and plate girder sections. These two sections are

somewhat similar in aerodynamic characteristics, and it is generally accepted that their geometry is poor from an aerodynamic standpoint. Of interest for the Original Quincy section was that the vortex shedding was observed for four bending modes in smooth flow as shown in Figure 20a. Spectral analysis was required to determine the actual modes that were excited. The four peaks shown correspond to the first symmetric, first asymmetric, third symmetric and third asymmetric vertical modes. The responses for both the third symmetric and third assymetric modes are greater than those corresponding to the first symmetric and first asymmetric modes respectively. The response in the first modes was a stationary sinusoidal curve, whereas the third modes responses were characterized by a random variation in amplitude. However, a calculation of the power spectrum of the third mode response verified that only one mode was predominantly participating (Fig. 25). The Strouhal number corresponding to the third modes is about twice the Strouhal number corresponding to the first modes. The existence of more than one Strouhal number for a given bluff body has been reported elsewhere. Reference 18 suggests that this phenomenon occuring on a 2:1 rectangular box is the result of differing vortices being shed from the leading and trailing edges. In the case of the Original Quincy section, the effect could be due to differing vortices being shed from the main girders and Jersey traffic barriers.

In the case of plate girder section, the addition of fairings eliminated any response due to vortex shedding. The plate girder section without fairings was the only section for which a clear indication of torsional response resulting from vortex shedding was observed.

4.2 Torsional Instability

The onset of torsional instability for a bridge road deck in smooth flow is characterized by a sudden, sharp increase in torsional amplitude as a function of wind speed. The effect of turbulence has been reported to be beneficial (Ref. 4), in that the turbulence serves

to break up the coherence and structure of the flow surrounding the body. It was of interest in this study to determine the capability of each of the two intensities of turbulence to delay or perhaps preclude the onset of torsional instability.

The onset of a torsional instability was not observed in any cases with the highly turbulent flow simulation. The large magnitude of deflections arising from vertical buffeting (greater than 5% of chord) at high windspeeds made it impractical to increase the wind speed much beyond that of the critical wind speed obtained from smooth flow testing. In the majority of cases, the severity of buffeting restricted testing in highly turbulent flow to wind speeds below the critical speed obtained in smooth flow.

The vertical buffeting response was considerably reduced in the slightly turbulent flow, making it possible to thoroughly investigate the onset of torsional instability in this flow. Figures 26 through 30 are logarithmic plots of the peak response (radians) versus reduced wind speed, for several deck sections. These data are replotted from Figures 20b through 25b.

It is possible in several of the figures to observe the transition from torsional buffeting to torsional instability. The torsional buffeting occurs at lower values of U_r. In the case of buffeting, the functional relationship between peak response and wind speed can be roughly described as

$$\hat{z} = kU_r^{\alpha} \tag{4.1}$$

where $\hat{z}$ is the peak response

U_r is the reduced wind speed

k is a constant for given conditions

and α is a constant, approximately 2.5 (Ref. 19)

This relationship would appear as a straight line with a slope of α on a logarithmic plot. For several cases, the value of α is 2.5 or slightly

greater; however, in other cases, α was as high as 6. This large value may suggest that the response is some combination of buffeting and torsional instability.

At the onset of transition to torsional instability in slightly turbulent flow, there is an "elbow" in the response curve in most cases, beyond which the slope increases dramatically. It can be seen that the critical speed is not altered drastically by the slightly turbulent flow.

The addition of fairings serves to raise the critical speed in each case. The largest increase in critical speed is found by changing the twin box section to a single box, where in smooth flow the increase is of the order of ten percent. This potentially represents a dramatic decrease in the probability that the critical wind speed will occur over the life of the structure

Of particular interest is the instability behaviour of the two Quincy sections. It can be seen that the instability begins at a slightly lower windspeed for the final section than for the original section. This behaviour is in contrast to that of vortex induced motion where it was shown that the final configuration is superior to the original section. This instability behaviour was verified in unpublished sectional model testing.

4.3 Buffeting

The response to buffeting of the various sections appears in Figures 20 through 25. The experimental results agreed well with analytically obtained values using data from Wardlaw et al (Ref. 14) for the Quincy sections, and the theory of Irwin (Ref. 19). These are the only sections for which the mean force and moment coefficients were available at the time of writing.

It is worth noting the reduced response of the single box section in comparison with that of the twin box section (Figs. 23 and 24). It is likely that reattachment of the flow is occuring on the single box section, which reduces the slope of the normal force curve, and hence the buffeting response. Also noteworthy is the reduced response resulting from the addition of fairings, likely for the same reasons.

A survey of the response curves indicates that the rms response is roughly proportional to the intensity of turbulence, which verifies the earlier works of Referencs 2 and 19.

On each of the curves in Figures 20 through 25, a small response can be seen at high reduced velocities in smooth flow. This response is likely due to wake buffeting; that is, the irregular pressure fluctuations in the wake region are of sufficient magnitude to displace the structure from its rest position. The deflections are much larger than could be attributed to buffeting resulting from the free stream turbulence in the wind tunnel.

5.0 CONCLUSIONS

Aerodynamic effects of turbulence and bridge deck section geometry on deck motion have been assessed in this experiment, with the use of a 1:75 scale full aeroelastic model of a contemporary cable-stayed bridge.

With respect to motions resulting from vortex shedding, it was found that in smooth flow the plate girder sections were susceptible, whereas the box sections were less vulnerable. The introduction of a 5% turbulence level to the mean flow was sufficient to arrest the motion. The motions were not observed in smooth flow for the plate girder sections with triangular fairings on the centre span.

In smooth flow at high wind speeds, a torsional instability was observed for all sections, except the composite girder section. The introduction of a 5% turbulence level to the mean flow had little effect on the velocity at which the torsional instability was first observed, although the slope of the amplitude versus velocity curves were reduced in the turbulent flow compared to the smooth flow.

The addition of fairings to a given section had the effect of raising the critical velocity for the onset of torisonal instability. The critical velocity was also increased when the two box section was modified to become a single box section. In general, the observed trend was that a more streamlined deck section had a higher critical velocity.

It was found that changes made to deck section geometry, in order to alleviate the effects of vortex shedding, could result in a reduction, albeit slight, of the critical velocity for the onset of torsional instability.

In a flow where the turbulence level in the mean flow direction was 12%, no torsional instabilities were observed. This was due to the large buffeting amplitudes present, which limited the wind speed to values at or below the critical speeds in smooth flow. This point is significant in two respects. The first is that no conclusions can be drawn from this experiment as to the effects of this level of atmospheric turbulence intensity on bridge deck torsional instability. The second is that proper consideration of the buffeting response is important in the design of these bridges.

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APPENDIX A

Dynamic Analysis

The dynamic analyses of both the Quincy Bridge and the aeroelastic model were carried out using "NISA", a finite element programme available at the National Research Council of Canada (NRCC). The analyses was done for the following four computer simulation models:

1) Modjeski & Masters model
2) Modified model
3) Two-spine model
4) Scaled model

The model 1) tried to reproduce the results of the dynamic modal analysis of the Quincy Bridge computed by Modjeski and Masters using the "STRUDL" program. The simulated structure model for this case is believed to be the same as for the STRUDL analysis. There are three elastic spines in the longitudinal direction of the bridge. The middle spine carries the lateral bending and torsional stiffness while the vertical bending stiffness is simulated by two side spines. Also the effect of the warping stiffness has been probably considered by the provision of these two side spines. The girder is connected to the tower only by the central spine. The torsional stiffness is calculated on the assumption that two main girders and the concrete bridge deck system are rigidly connected and would work together as a C-shaped channel.

The model (2) tried to simplify the previous model by replacing the three spines by only one elastic bar which provides all three stiffnesses. The position of this bar is at the shear centre of the cross-section, in order that the boundary conditions at the supports would become more realistic. As it is shown at the end of this chapter, the results of the analysis are much the same as model (1).

If the connections between the deck and the plate girders are not stiff enough to fully transmit the moment, the torsional stiffness of the bridge will decrease and the location of shear centre will also be lowered. Another extreme case occurs therefore, when these connections have no resistance against the moment. In this case, torsion of the bridge simply means the two main girders' vertical motions are out of phase with respect to each other. The model (3) results from this. Note that the lateral stiffness is not well simulated in this model. In reality, the behavior of the bridge would be somewhere in-between models (2) and (3).

The aeroelastic model has two spines rather than a channel to represent stiffnesses and is designed to simulate the most likely behaviour of the bridge.

The results of the analysis are summarized as follows:

	1st Bend (Sym.)	2nd Bend (Asym.)	3rd Bend (Sym.)	Lat	Lat-Tors	Tors
Modjeski and Masters Model	0.360(Hz)	0.493	0.756	-	0.611 0.640	-
Modified Model	0.367	0.497	0.762	-	0.596	0.770
2 Spine Model	0.317	0.425	0.682	-	0.669	0.544
Scaled Model (1:75 Aeroelastic model)	5.132	6.44	10.182	8.225	-	12.059

APPENDIX B

Analysis of Results

The actual testing proceeded quite smoothly, with the result that all nine deck sections were tested in each of three flow

conditions. This resulted in about 14 MB of data which had to be processed.

The initial interest was to calculate the peak (minima and maxima) and root mean square responses (rms) of the nine deck sections as a function of mean wind speed. The data were transferred from the Megadac to an IBM-PC/AT. The PC has a 20 MB hard disk, allowing all of the data to be stored at once.

The initial software calculations of peak and rms values were performed on the entire time history, about 2400 samples per channel per wind speed. The results of the calculations produced peak and rms values up to several orders of magnitude larger than expected. Upon examination of the time histories of the transducer channels, it was found that large spikes were present in the data, roughly occuring every 1000th data point. To overcome this problem, the software analysis was altered to use only the first 800 points to compute the peak and rms values. The results were much improved. The source of these spikes has not been determined.

Frequency domain analysis of the bridge displacements was also of interest. Rather than performing an FFT in software, it was found that more accurate estimates of the response spectra could be obtained using a two channel spectrum analyzer, an HP-5423A in this case. The HP analyzer has the capability to perform averages by overlapping the data, thus producing smooth spectral averages (Fig. B1).

The data were output through digital-to-analog ports on the Megadac unit. The analog signals were low pass fitered at 20 Hz using the filters described previously, and then sum-and-differenced to produce signals proportional to the bending and torsional deflections. These two signals were sent to the HP analyzer, which was set-up to compute the average of 40 spectral estimates, over the range from 0 to 16 Hz, with a frequency resolution of 0.0625 Hz. The spikes that are present in the data did not have a large effect on the computed spectra.

During the computation of power spectra of torsional instability vibrations, it was noticed that there was a decrease in the response frequency with increasing windspeed through the instability regime in both smooth flow and slightly turbulent flow. This phenomenon was further investigated in detail for the original and final Quincy sections and the plate girder section. The shift in frequency is only about 10% (12 Hz to 11 Hz) for U/f_oB increasing from 4 to 7 (Fig. B2). The source of this frequency shift is likely an aerodynamic stiffness occuring at high wind speeds. The presence of turbulence in the flow serves to increase the magnitude of the aerodynamic stiffness.

A typical time record of the instability vibration in low turbulent flow is shown in Figure B4. Spectral analysis of this signal produced a spectrum with two closely spaced peaks, indicative of a beating motion. The beat phenomenon was rejected on physical grounds, since it is likely that only one torsional mode is participating. A probable explanation for the apparent beating is that the presence of turbulence forces the torsional vibration to compete with vertical buffeting motions and that over a period of time one and then the other dominates, (Fig. B5). At higher turbulence levels, the torsional instability is supressed completely by the turbulence.

In order to circumvent the beat frequency, weighted spectral averages were calculated. The weighting process used was of the form

$$A_i = \frac{(K-1)\ A_{i-1} + Z_i}{K} \qquad i \geq 2 \qquad \text{B.1}$$

where A_i is the ith weighted spectrum estimate, Z_i is the ith raw spectrum estimate and K is a weighting factor (note that K=1 implies that all estimates are weighted equally). In the earlier spectral calculations, each of the 40 spectra were equally weighted.

The value of K chosen was 2, thus equation B.1 collapses to

$$A_i = \frac{Z_i}{2} + \frac{Z_{i-1}}{4} + \frac{Z_{i-2}}{8} + \ldots + \frac{Z_{i-n}}{2^{n+1}} \qquad \text{B.2}$$

Because these spectral estimates are heavily weighted by the most recently computed estimates, the effect of the slowly varying motion is severly reduced, and estimates of the frequency at which the peak response occured are easy to determine, since there is only a single peak present. It is accepted that the magnitude of the peaks will be in error because of this weighting process, however they were not of interest here.

The frequency domain analysis was used in two other areas. The first was to sort out the vortex shedding response of the original Quincy section in smooth flow. During the testing, it was found that this section could be excited in many bending modes depending on the wind speed. The power spectra of the response were then compared with the finite element dynamic analysis of the model to determine in which mode the model was responding. In most cases, the computed response frequency agreed with the finite element analysis to within 2%. The highest mode detected was the third asymmetric bending mode (6th bending) which had a frequency of 16.4 Hz. A more detailed discussion can be found in Reference 20.

APPENDIX C

ORIGINAL QUINCY IN SMOOTH FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	1.235								
RMS =	0.104	4.266E-03	3.511E-03	3.658E-02	3.041E-02	2.165E-02	2.565E-03	2.865E-02	3.751E-01
MAX =	0.333	8.098E-03	1.240E-02	5.756E-02	6.582E-02	3.444E-02	6.363E-03	4.636E-02	5.803E-01
RATIO=	3.192	1.898E+00	3.531E+00	1.574E+00	2.164E+00	1.591E+00	2.481E+00	1.618E+00	1.547E+00
MEAN =	0.842								
RMS =	0.110	3.089E-02	4.546E-03	7.869E-03	2.270E-02	4.421E-03	1.664E-03	6.571E-03	6.222E-02
MAX =	0.288	4.824E-02	1.339E-02	1.277E-02	4.124E-02	6.921E-03	4.254E-03	1.065E-02	9.727E-02
RATIO=	2.617	1.562E+00	2.946E+00	1.623E+00	1.817E+00	1.566E+00	2.556E+00	1.620E+00	1.563E+00
MEAN =	3.828								
RMS =	0.080	6.317E-03	1.756E-02	1.576E-02	2.774E-02	1.105E-02	4.574E-03	1.950E-02	5.705E-01
MAX =	0.215	1.968E-02	5.281E-02	2.662E-02	5.912E-02	1.925E-02	1.072E-02	3.279E-02	8.930E-01
RATIO=	2.701	3.115E+00	3.007E+00	1.689E+00	2.131E+00	1.742E+00	2.343E+00	1.681E+00	1.565E+00
MEAN =	4.773								
RMS =	0.080	4.747E-02	2.533E-02	4.168E-02	3.551E-02	2.401E-02	8.278E-03	5.094E-03	1.872E-01
MAX =	0.269	8.755E-02	7.810E-02	7.233E-02	7.977E-02	4.125E-02	2.570E-02	1.244E-02	3.744E-01
RATIO=	3.348	1.844E+00	3.084E+00	1.735E+00	2.246E+00	1.718E+00	3.105E+00	2.442E+00	2.000E+00
MEAN =	5.213								
RMS =	0.101	1.223E-02	3.183E-02	6.404E-02	5.323E-02	3.444E-02	1.093E-02	4.824E-03	2.663E-01
MAX =	0.280	3.946E-02	8.833E-02	1.094E-01	1.181E-01	5.781E-02	3.035E-02	1.315E-02	4.763E-01
RATIO=	2.779	3.227E+00	2.775E+00	1.709E+00	2.218E+00	1.678E+00	2.776E+00	2.726E+00	1.789E+00
MEAN =	5.809								
RMS =	0.079	1.052E-02	1.696E-02	7.330E-02	5.875E-02	3.913E-02	1.102E-02	5.103E-03	2.958E-01
MAX =	0.266	3.140E-02	4.829E-02	1.264E-01	1.295E-01	6.419E-02	3.074E-02	1.332E-02	5.821E-01
RATIO=	3.361	2.985E+00	2.848E+00	1.724E+00	2.205E+00	1.641E+00	2.789E+00	2.610E+00	1.968E+00
MEAN =	2.057								
RMS =	0.081	5.570E-03	4.669E-03	4.631E-02	2.920E-02	2.625E-02	1.059E-02	3.550E-02	4.643E-01
MAX =	0.245	1.056E-02	1.478E-02	7.262E-02	5.350E-02	4.107E-02	2.058E-02	5.301E-02	7.032E-01
RATIO=	3.013	1.895E+00	3.165E+00	1.568E+00	1.832E+00	1.564E+00	1.943E+00	1.493E+00	1.515E+00
MEAN =	1.841								
RMS =	0.073	5.108E-03	3.367E-03	2.707E-02	1.470E-02	3.247E-02	3.755E-01	2.057E-02	2.701E-01
MAX =	0.219	1.007E-02	1.055E-02	4.430E-02	3.112E-02	5.231E-02	5.523E-01	3.200E-02	4.223E-01
RATIO=	2.999	1.970E+00	3.132E+00	1.636E+00	2.118E+00	1.611E+00	1.471E+00	1.555E+00	1.563E+00
MEAN =	1.687								
RMS =	0.075	6.332E-03	4.350E-03	3.822E-02	1.586E-02	4.539E-02	5.253E-01	2.861E-02	3.731E-01
MAX =	0.214	1.007E-02	1.080E-02	6.131E-02	3.311E-02	7.140E-02	7.946E-01	4.480E-02	5.774E-01
RATIO=	2.845	1.590E+00	2.484E+00	1.604E+00	2.088E+00	1.573E+00	1.513E+00	1.566E+00	1.547E+00
MEAN =	1.453								
RMS =	0.076	6.771E-03	5.118E-03	4.125E-02	1.707E-02	4.872E-02	5.640E-01	3.071E-02	4.008E-01
MAX =	0.225	1.240E-02	1.264E-02	6.286E-02	4.298E-02	7.414E-02	8.000E-01	4.482E-02	5.952E-01
RATIO=	2.981	1.831E+00	2.469E+00	1.524E+00	2.518E+00	1.522E+00	1.418E+00	1.459E+00	1.485E+00

ORIGINAL QUINCY IN SMOOTH FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	1.187								
RMS =	0.077	5.003E-03	2.322E-03	1.356E-03	1.052E-02	1.447E-03	1.723E-02	1.001E-03	1.025E-02
MAX =	0.221	1.068E-02	7.536E-03	3.214E-03	2.193E-02	3.321E-03	4.307E-02	2.196E-03	2.494E-02
RATIO=	2.882	2.134E+00	3.245E+00	2.370E+00	2.085E+00	2.295E+00	2.499E+00	2.193E+00	2.433E+00
MEAN =	1.189								
RMS =	0.075	7.997E-03	2.332E-03	2.100E-03	1.212E-02	2.252E-03	2.633E-02	1.583E-03	1.552E-02
MAX =	0.309	1.805E-02	8.265E-03	5.518E-03	2.240E-02	5.712E-03	6.093E-02	3.710E-03	3.872E-02
RATIO=	4.120	2.258E+00	3.544E+00	2.627E+00	1.848E+00	2.537E+00	2.314E+00	2.343E+00	2.494E+00
MEAN =	1.294								
RMS =	0.077	9.243E-03	2.300E-03	2.430E-03	1.097E-02	2.550E-03	3.001E-02	1.798E-03	1.752E-02
MAX =	0.224	1.858E-02	7.431E-03	4.847E-03	2.171E-02	5.028E-03	5.896E-02	3.570E-03	3.970E-02
RATIO=	2.922	2.010E+00	3.230E+00	1.995E+00	1.978E+00	1.972E+00	1.965E+00	1.985E+00	2.266E+00
MEAN =	1.213								
RMS =	0.074	1.838E-02	2.706E-03	4.768E-03	1.098E-02	5.205E-03	6.062E-02	3.679E-03	3.470E-02
MAX =	0.223	3.730E-02	9.363E-03	9.643E-03	1.961E-02	1.056E-02	1.220E-01	7.176E-03	6.396E-02
RATIO=	3.026	2.029E+00	3.424E+00	2.022E+00	1.804E+00	2.029E+00	2.012E+00	1.951E+00	1.843E+00
MEAN =	11.477								
RMS =	0.131	2.665E-02	8.448E-02	1.350E-02	3.585E-02	1.537E-02	1.805E-01	8.689E-03	1.380E-01
MAX =	0.330	9.199E-02	2.615E-01	3.595E-02	1.126E-01	5.114E-02	6.003E-01	2.862E-02	3.798E-01
RATIO=	2.526	3.452E+00	3.096E+00	2.662E+00	3.141E+00	3.327E+00	3.325E+00	3.293E+00	2.752E+00
MEAN =	12.625								
RMS =	0.085	3.228E-02	8.065E-02	1.470E-02	3.491E-02	1.720E-02	2.009E-01	9.608E-03	1.588E-01
MAX =	0.394	9.550E-02	2.424E-01	4.622E-02	1.138E-01	4.942E-02	7.048E-01	2.922E-02	5.294E-01
RATIO=	4.655	2.958E+00	3.005E+00	3.145E+00	3.260E+00	2.873E+00	3.507E+00	3.041E+00	3.333E+00
MEAN =	13.773								
RMS =	0.089	4.021E-02	1.936E-01	1.673E-02	5.683E-02	1.962E-02	2.329E-01	1.059E-02	1.718E-01
MAX =	0.424	1.315E-01	4.654E-01	5.017E-02	1.630E-01	7.031E-02	6.446E-01	3.791E-02	4.542E-01
RATIO=	4.779	3.270E+00	2.405E+00	2.998E+00	2.868E+00	3.584E+00	2.768E+00	3.580E+00	2.644E+00
MEAN =	13.314								
RMS =	0.081	3.590E-02	1.995E-01	1.648E-02	6.045E-02	1.826E-02	2.217E-01	9.869E-03	1.616E-01
MAX =	0.505	1.004E-01	5.141E-01	5.604E-02	1.561E-01	5.289E-02	7.096E-01	3.316E-02	4.694E-01
RATIO=	6.238	2.796E+00	2.577E+00	3.401E+00	2.582E+00	2.897E+00	3.201E+00	3.360E+00	2.905E+00
MEAN =	14.232								
RMS =	0.086	4.062E-02	2.715E-01	1.883E-02	7.623E-02	2.233E-02	2.672E-01	1.272E-02	1.950E-01
MAX =	0.495	1.177E-01	5.617E-01	6.103E-02	1.737E-01	7.617E-02	7.747E-01	4.745E-02	6.423E-01
RATIO=	5.780	2.898E+00	2.069E+00	3.241E+00	2.279E+00	3.411E+00	2.899E+00	3.729E+00	3.294E+00
MEAN =	14.691								
RMS =	0.083	3.367E-02	2.537E-01	1.655E-02	7.195E-02	1.913E-02	2.321E-01	1.005E-02	1.858E-01
MAX =	0.398	9.632E-02	7.101E-01	4.545E-02	2.290E-01	5.687E-02	8.623E-01	3.014E-02	7.318E-01
RATIO=	4.802	2.861E+00	2.798E+00	2.746E+00	3.182E+00	2.972E+00	3.715E+00	3.000E+00	3.939E+00

ORIGINAL QUINCY IN SMOOTH FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	15.150								
RMS =	0.101	4.745E-02	6.870E-01	1.999E-02	1.834E-01	2.261E-02	3.053E-01	1.390E-02	2.258E-01
MAX =	0.511	1.509E-01	1.192E+00	5.067E-02	3.525E-01	6.274E-02	1.095E+00	4.735E-02	6.076E-01
RATIO=	5.043	3.179E+00	1.736E+00	2.535E+00	1.923E+00	2.774E+00	3.586E+00	3.408E+00	2.691E+00

ORIGINAL QUINCY IN LOW TURBULENT FLOW

	WIND SPEED	CENTER		S.CENTER		N.CENTER		SIDE SPAN	
	(M/SEC)	BND(CM)	TOR(DEG.)	BND(CM)	TOR(DEG.)	BND(CM)	TOR(DEG.)	BND(CM)	TOR(DEG.)
MEAN =	2.216								
RMS =	0.068	3.127E-03	3.243E-03	9.055E-03	2.330E-02	5.171E-03	2.451E-03	6.964E-03	9.232E-02
MAX =	0.192	8.010E-03	9.190E-03	1.710E-02	3.986E-02	9.684E-03	6.966E-03	1.329E-02	1.704E-01
RATIO=	2.834	2.562E+00	2.834E+00	1.888E+00	1.711E+00	1.873E+00	2.842E+00	1.909E+00	1.845E+00
MEAN =	3.497								
RMS =	0.068	1.097E-02	6.667E-03	3.292E-03	2.588E-02	1.601E-03	1.764E-03	2.650E-03	4.471E-02
MAX =	0.242	3.734E-02	2.077E-02	1.129E-02	4.433E-02	5.324E-03	5.838E-03	8.002E-03	1.306E-01
RATIO=	3.559	3.402E+00	3.115E+00	3.428E+00	1.713E+00	3.326E+00	3.310E+00	3.020E+00	2.921E+00
MEAN =	3.742								
RMS =	0.062	1.155E-02	1.668E-02	1.355E-02	2.357E-02	9.075E-03	4.931E-03	1.645E-02	4.769E-01
MAX =	0.212	3.783E-02	4.609E-02	2.575E-02	5.411E-02	1.933E-02	1.183E-02	3.363E-02	7.841E-01
RATIO=	3.410	3.274E+00	2.764E+00	1.901E+00	2.295E+00	2.130E+00	2.400E+00	2.044E+00	1.644E+00
MEAN =	4.921								
RMS =	0.061	2.387E-02	2.699E-02	1.735E-02	2.461E-02	9.933E-03	5.315E-03	4.499E-03	8.863E-02
MAX =	0.192	6.373E-02	7.512E-02	4.044E-02	5.172E-02	2.347E-02	1.657E-02	1.353E-02	2.589E-01
RATIO=	3.165	2.670E+00	2.783E+00	2.330E+00	2.101E+00	2.363E+00	3.118E+00	3.006E+00	2.922E+00
MEAN =	5.591								
RMS =	0.068	2.971E-02	2.926E-02	1.034E-02	2.884E-02	5.612E-03	8.025E-03	7.540E-03	9.302E-02
MAX =	0.215	8.213E-02	7.639E-02	3.087E-02	7.924E-02	1.700E-02	2.615E-02	2.105E-02	3.529E-01
RATIO=	3.154	2.764E+00	2.611E+00	2.987E+00	2.747E+00	3.029E+00	3.259E+00	2.792E+00	3.793E+00
MEAN =	8.411								
RMS =	0.099	4.287E-02	9.353E-02	1.670E-02	3.285E-02	1.982E-02	2.354E-01	1.252E-02	1.619E-01
MAX =	0.310	1.126E-01	2.990E-01	5.051E-02	1.008E-01	6.737E-02	7.872E-01	3.815E-02	4.866E-01
RATIO=	3.140	2.626E+00	3.197E+00	3.025E+00	3.069E+00	3.399E+00	3.345E+00	3.048E+00	3.005E+00
MEAN =	9.632								
RMS =	0.090	8.780E-02	9.587E-02	2.899E-02	3.901E-02	3.276E-02	3.858E-01	2.132E-02	2.662E-01
MAX =	0.280	2.793E-01	2.948E-01	1.123E-01	1.043E-01	1.183E-01	1.336E+00	6.920E-02	8.537E-01
RATIO=	3.097	3.181E+00	3.075E+00	3.873E+00	2.674E+00	3.610E+00	3.465E+00	3.246E+00	3.207E+00
MEAN =	11.559								
RMS =	0.124	1.108E-01	2.924E-01	4.061E-02	8.542E-02	4.634E-02	5.507E-01	2.924E-02	3.725E-01
MAX =	0.579	3.291E-01	8.055E-01	1.224E-01	2.325E-01	1.495E-01	1.849E+00	8.097E-02	1.448E+00
RATIO=	4.661	2.970E+00	2.755E+00	3.013E+00	2.722E+00	3.227E+00	3.358E+00	2.769E+00	3.886E+00
MEAN =	12.522								
RMS =	0.117	1.012E-01	1.898E-01	4.256E-02	6.377E-02	4.622E-02	5.469E-01	2.799E-02	3.847E-01
MAX =	0.676	2.826E-01	4.801E-01	1.339E-01	2.292E-01	1.561E-01	1.628E+00	9.074E-02	1.340E+00
RATIO=	5.761	2.793E+00	2.529E+00	3.145E+00	3.595E+00	3.377E+00	2.976E+00	3.242E+00	3.483E+00
MEAN =	13.485								
RMS =	0.107	1.230E-01	3.779E-01	4.699E-02	1.105E-01	5.167E-02	6.150E-01	3.261E-02	4.289E-01
MAX =	0.697	4.088E-01	9.815E-01	1.515E-01	2.589E-01	1.870E-01	1.821E+00	1.299E-01	1.418E+00
RATIO=	6.527	3.323E+00	2.597E+00	3.225E+00	2.343E+00	3.619E+00	2.962E+00	3.984E+00	3.306E+00

ORIGINAL QUINCY IN LOW TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	14.448								
RMS =	0.147	1.192E-01	7.372E-01	5.172E-02	2.005E-01	6.001E-02	7.322E-01	3.571E-02	4.734E-01
MAX =	0.686	4.661E-01	1.684E+00	1.731E-01	4.960E-01	2.039E-01	2.577E+00	1.355E-01	1.696E+00
RATIO=	4.675	3.910E+00	2.284E+00	3.348E+00	2.473E+00	3.398E+00	3.520E+00	3.794E+00	3.581E+00
MEAN =	15.412								
RMS =	0.198	1.608E-01	2.512E+00	5.687E-02	6.990E-01	7.293E-02	1.166E+00	3.871E-02	5.291E-01
MAX =	0.929	5.029E-01	5.051E+00	1.873E-01	1.779E+00	3.039E-01	2.897E+00	1.123E-01	1.679E+00
RATIO=	4.689	3.127E+00	2.011E+00	3.292E+00	2.545E+00	4.166E+00	2.484E+00	2.901E+00	3.174E+00

ORIGINAL QUINCY IN HIGH TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	CENTER TOR(DEG.)	S.CENTER BND(CM)	S.CENTER TOR(DEG.)	N.CENTER BND(CM)	N.CENTER TOR(DEG.)	SIDE SPAN BND(CM)	SIDE SPAN TOR(DEG.)
MEAN =	2.760								
RMS =	0.057	9.895E-03	5.365E-03	3.534E-03	2.332E-02	1.825E-03	1.765E-03	2.693E-03	3.177E-02
MAX =	0.200	2.715E-02	1.700E-02	1.255E-02	3.973E-02	5.548E-03	5.237E-03	8.909E-03	1.099E-01
RATIO=	3.523	2.744E+00	3.169E+00	3.551E+00	1.703E+00	3.040E+00	2.968E+00	3.308E+00	3.459E+00
MEAN =	3.355								
RMS =	0.068	1.532E-02	1.718E-02	4.999E-03	2.272E-02	2.727E-03	2.993E-03	4.030E-03	4.594E-02
MAX =	0.249	4.747E-02	4.791E-02	1.507E-02	4.618E-02	7.877E-03	1.057E-02	1.493E-02	1.506E-01
RATIO=	3.683	3.099E+00	2.788E+00	3.015E+00	2.033E+00	2.888E+00	3.533E+00	3.706E+00	3.277E+00
MEAN =	7.025								
RMS =	0.133	7.241E-02	6.160E-02	2.422E-02	3.625E-02	1.398E-02	1.261E-02	1.926E-02	2.192E-01
MAX =	0.369	2.089E-01	1.979E-01	6.616E-02	1.006E-01	5.057E-02	3.878E-02	4.778E-02	7.046E-01
RATIO=	2.767	2.884E+00	3.212E+00	2.731E+00	2.774E+00	3.617E+00	3.075E+00	2.480E+00	3.214E+00

FINAL QUINCY IN SMOOTH FLOW

	WIND SPEED	CENTER		S.CENTER		N.CENTER		SIDE SPAN	
	(M/SEC)	BND(CM)	TOR(DEG.)	BND(CM)	TOR(DEG.)	BND(CM)	TOR(DEG.)	BND(CM)	TOR(DEG.)
MEAN =	4.005								
RMS =	0.070	1.115E-02	1.315E-02	5.528E-03	7.441E-02	7.723E-03	9.287E-02	2.400E-03	4.050E-02
MAX =	0.211	3.547E-02	3.932E-02	1.668E-02	1.796E-01	1.981E-02	2.686E-01	9.180E-03	1.228E-01
RATIO=	3.040	3.180E+00	2.991E+00	3.018E+00	2.414E+00	2.566E+00	2.892E+00	3.825E+00	3.032E+00
MEAN =	6.449								
RMS =	0.077	1.391E-02	1.897E-02	5.069E-03	6.290E-02	6.490E-03	7.798E-02	3.778E-03	5.839E-02
MAX =	0.257	4.197E-02	5.046E-02	1.723E-02	1.776E-01	1.945E-02	3.327E-01	1.194E-02	2.027E-01
RATIO=	3.322	3.018E+00	2.660E+00	3.400E+00	2.824E+00	2.997E+00	4.266E+00	3.159E+00	3.472E+00
MEAN =	9.117								
RMS =	0.105	2.120E-02	4.811E-02	7.535E-03	8.221E-02	9.683E-03	1.170E-01	5.749E-03	9.043E-02
MAX =	0.336	6.950E-02	1.468E-01	2.575E-02	2.375E-01	2.881E-02	3.717E-01	1.868E-02	2.904E-01
RATIO=	3.185	3.278E+00	3.053E+00	3.417E+00	2.889E+00	2.976E+00	3.178E+00	3.248E+00	3.211E+00
MEAN =	11.477								
RMS =	0.083	2.826E-02	1.359E-01	9.836E-03	1.177E-01	1.332E-02	1.640E-01	7.624E-03	1.204E-01
MAX =	0.299	8.729E-02	3.064E-01	3.225E-02	4.123E-01	3.998E-02	5.345E-01	2.431E-02	3.562E-01
RATIO=	3.619	3.088E+00	2.255E+00	3.279E+00	3.503E+00	3.001E+00	3.259E+00	3.188E+00	2.958E+00
MEAN =	12.625								
RMS =	0.087	3.255E-02	1.648E-01	1.237E-02	1.417E-01	1.534E-02	1.896E-01	8.670E-03	1.488E-01
MAX =	0.310	1.019E-01	4.378E-01	3.974E-02	4.260E-01	5.351E-02	5.943E-01	2.862E-02	5.307E-01
RATIO=	3.564	3.131E+00	2.657E+00	3.212E+00	3.007E+00	3.489E+00	3.134E+00	3.301E+00	3.567E+00
MEAN =	13.773								
RMS =	0.089	3.042E-02	2.039E-01	1.230E-02	1.546E-01	1.617E-02	2.022E-01	8.759E-03	1.519E-01
MAX =	0.401	8.771E-02	5.069E-01	4.208E-02	4.544E-01	4.994E-02	7.219E-01	3.119E-02	4.331E-01
RATIO=	4.530	2.883E+00	2.486E+00	3.421E+00	2.939E+00	3.088E+00	3.571E+00	3.561E+00	2.850E+00
MEAN =	14.920								
RMS =	0.082	5.296E-02	1.478E+00	1.509E-02	4.145E-01	2.074E-02	4.614E-01	1.060E-02	2.079E-01
MAX =	0.434	1.446E-01	2.335E+00	4.800E-02	9.173E-01	5.677E-02	1.010E+00	2.961E-02	6.338E-01
RATIO=	5.301	2.730E+00	1.580E+00	3.181E+00	2.213E+00	2.737E+00	2.190E+00	2.792E+00	3.049E+00

FINAL QUINCY IN LOW TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	4.910								
RMS =	0.069	1.353E-02	1.358E-02	4.898E-03	4.607E-02	6.232E-03	7.476E-02	3.553E-03	4.663E-02
MAX =	0.211	3.912E-02	4.045E-02	1.398E-02	1.316E-01	1.826E-02	1.996E-01	9.636E-03	1.245E-01
RATIO=	3.058	2.892E+00	2.978E+00	2.855E+00	2.856E+00	2.930E+00	2.670E+00	2.712E+00	2.670E+00
MEAN =	5.797								
RMS =	0.072	1.894E-02	2.564E-02	6.689E-03	6.610E-02	8.488E-03	1.016E-01	4.873E-03	6.747E-02
MAX =	0.211	6.538E-02	8.296E-02	2.083E-02	2.093E-01	3.045E-02	3.050E-01	1.608E-02	2.168E-01
RATIO=	2.908	3.452E+00	3.236E+00	3.114E+00	3.166E+00	3.587E+00	3.002E+00	3.299E+00	3.213E+00
MEAN =	6.651								
RMS =	0.071	2.948E-02	4.129E-02	1.007E-02	7.669E-02	1.230E-02	1.481E-01	7.864E-03	9.656E-02
MAX =	0.219	7.222E-02	1.219E-01	3.590E-02	2.531E-01	3.924E-02	5.768E-01	3.283E-02	3.201E-01
RATIO=	3.067	2.450E+00	2.951E+00	3.565E+00	3.301E+00	3.190E+00	3.894E+00	4.174E+00	3.315E+00
MEAN =	7.706								
RMS =	0.084	5.813E-02	6.587E-02	1.889E-02	1.335E-01	2.372E-02	2.846E-01	1.553E-02	1.873E-01
MAX =	0.344	1.522E-01	1.883E-01	6.150E-02	3.806E-01	7.107E-02	8.119E-01	4.399E-02	6.484E-01
RATIO=	4.099	2.619E+00	2.858E+00	3.255E+00	2.850E+00	2.997E+00	2.853E+00	2.832E+00	3.461E+00
MEAN =	9.632								
RMS =	0.091	6.805E-02	1.055E-01	2.396E-02	1.944E-01	3.134E-02	3.760E-01	1.954E-02	2.602E-01
MAX =	0.259	1.928E-01	3.446E-01	6.892E-02	6.393E-01	1.350E-01	1.227E+00	8.071E-02	1.094E+00
RATIO=	2.849	2.834E+00	3.266E+00	2.876E+00	3.288E+00	4.307E+00	3.265E+00	4.130E+00	4.206E+00
MEAN =	12.522								
RMS =	0.104	1.042E-01	3.010E-01	3.872E-02	3.415E-01	4.845E-02	5.845E-01	3.028E-02	4.172E-01
MAX =	0.500	2.945E-01	8.483E-01	1.160E-01	1.156E+00	1.596E-01	2.026E+00	9.323E-02	1.262E+00
RATIO=	4.817	2.827E+00	2.818E+00	2.997E+00	3.384E+00	3.294E+00	3.466E+00	3.079E+00	3.026E+00
MEAN =	11.559								
RMS =	0.074	1.127E-01	2.257E-01	3.431E-02	2.810E-01	4.227E-02	5.091E-01	2.696E-02	3.292E-01
MAX =	0.347	3.873E-01	6.159E-01	1.192E-01	9.639E-01	1.381E-01	1.656E+00	8.014E-02	1.023E+00
RATIO=	4.681	3.438E+00	2.729E+00	3.473E+00	3.430E+00	3.267E+00	3.252E+00	2.972E+00	3.106E+00
MEAN =	12.522								
RMS =	0.080	1.089E-01	3.256E-01	4.073E-02	3.418E-01	4.890E-02	5.919E-01	3.081E-02	4.121E-01
MAX =	0.460	3.270E-01	8.169E-01	1.257E-01	1.028E+00	1.501E-01	1.860E+00	1.062E-01	1.344E+00
RATIO=	5.758	3.002E+00	2.509E+00	3.087E+00	3.008E+00	3.070E+00	3.143E+00	3.446E+00	3.262E+00
MEAN =	13.485								
RMS =	0.091	1.216E-01	2.676E-01	4.227E-02	3.871E-01	5.101E-02	6.149E-01	3.125E-02	4.250E-01
MAX =	0.438	3.446E-01	7.869E-01	1.274E-01	1.125E+00	1.820E-01	2.075E+00	1.066E-01	1.456E+00
RATIO=	4.810	2.834E+00	2.941E+00	3.013E+00	2.906E+00	3.568E+00	3.375E+00	3.412E+00	3.426E+00
MEAN =	14.448								
RMS =	0.087	1.119E-01	1.137E+00	4.467E-02	4.978E-01	5.493E-02	7.297E-01	3.213E-02	4.591E-01
MAX =	0.571	4.017E-01	2.200E+00	1.432E-01	1.688E+00	2.223E-01	2.631E+00	1.014E-01	1.541E+00
RATIO=	6.599	3.588E+00	1.935E+00	3.204E+00	3.391E+00	4.047E+00	3.606E+00	3.156E+00	3.356E+00

FINAL QUINCY IN LOW TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	15.412								
RMS =	0.085	1.248E-01	1.527E+00	4.748E-02	6.137E-01	6.602E-02	9.395E-01	3.636E-02	5.176E-01
MAX =	0.469	4.299E-01	3.574E+00	1.712E-01	1.982E+00	2.428E-01	2.920E+00	1.120E-01	1.451E+00
RATIO=	5.552	3.444E+00	2.341E+00	3.605E+00	3.229E+00	3.679E+00	3.108E+00	3.081E+00	2.804E+00

FINAL QUINCY IN HIGH TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND (CM)	TOR (DEG.)	S. CENTER BND (CM)	TOR (DEG.)	N. CENTER BND (CM)	TOR (DEG.)	SIDE SPAN BND (CM)	TOR (DEG.)
MEAN =	3.417								
RMS =	0.128	1.306E-02	1.231E-02	3.771E-03	2.494E-02	4.261E-03	5.230E-02	2.903E-03	3.070E-02
MAX =	0.301	3.750E-02	4.846E-02	1.102E-02	9.015E-02	1.764E-02	1.393E-01	7.558E-03	8.406E-02
RATIO=	2.350	2.872E+00	3.938E+00	2.923E+00	3.615E+00	4.140E+00	2.664E+00	2.603E+00	2.739E+00
MEAN =	4.285								
RMS =	0.167	2.182E-02	3.495E-02	7.091E-03	4.906E-02	8.671E-03	1.067E-01	5.633E-03	6.793E-02
MAX =	0.444	6.660E-02	1.210E-01	2.210E-02	1.483E-01	2.951E-02	4.189E-01	2.010E-02	2.058E-01
RATIO=	2.653	3.052E+00	3.461E+00	3.116E+00	3.023E+00	3.403E+00	3.927E+00	3.569E+00	3.029E+00
MEAN =	5.540								
RMS =	0.089	4.013E-02	3.116E-02	1.245E-02	7.990E-02	1.400E-02	1.718E-01	9.392E-03	1.033E-01
MAX =	0.313	1.219E-01	8.798E-02	4.161E-02	2.788E-01	4.440E-02	5.555E-01	2.870E-02	2.486E-01
RATIO=	3.541	3.038E+00	2.823E+00	3.343E+00	3.489E+00	3.172E+00	3.233E+00	3.056E+00	2.408E+00
MEAN =	5.913								
RMS =	0.135	5.582E-02	5.546E-02	1.790E-02	1.155E-01	2.052E-02	2.511E-01	1.343E-02	1.477E-01
MAX =	0.374	1.465E-01	1.695E-01	5.938E-02	3.529E-01	6.823E-02	7.438E-01	3.787E-02	4.209E-01
RATIO=	2.783	2.525E+00	3.056E+00	3.317E+00	3.057E+00	3.325E+00	2.962E+00	2.821E+00	2.850E+00
MEAN =	6.532								
RMS =	0.112	7.911E-02	7.723E-02	2.320E-02	1.535E-01	2.715E-02	3.334E-01	1.839E-02	2.004E-01
MAX =	0.353	2.780E-01	2.607E-01	7.287E-02	4.590E-01	8.139E-02	1.017E+00	5.541E-02	5.240E-01
RATIO=	3.153	3.559E+00	3.375E+00	3.141E+00	2.989E+00	2.998E+00	3.050E+00	3.014E+00	2.615E+00
MEAN =	7.618								
RMS =	0.119	1.146E-01	8.740E-02	3.411E-02	2.052E-01	3.903E-02	4.785E-01	2.636E-02	2.861E-01
MAX =	0.303	3.209E-01	2.755E-01	1.036E-01	8.899E-01	1.343E-01	1.450E+00	8.595E-02	9.923E-01
RATIO=	2.576	2.800E+00	3.152E+00	3.038E+00	4.337E+00	3.441E+00	3.031E+00	3.261E+00	3.469E+00
MEAN =	7.901								
RMS =	0.161	9.686E-02	1.197E-01	3.308E-02	2.373E-01	3.948E-02	4.857E-01	2.564E-02	3.175E-01
MAX =	0.328	3.375E-01	3.008E-01	1.339E-01	7.831E-01	1.209E-01	1.394E+00	7.119E-02	9.017E-01
RATIO=	2.041	3.485E+00	2.512E+00	4.048E+00	3.300E+00	3.063E+00	2.870E+00	2.776E+00	2.840E+00
MEAN =	7.901								
RMS =	0.156	8.135E-02	1.063E-01	2.985E-02	4.097E-02	3.475E-02	4.040E-01	2.191E-02	2.685E-01
MAX =	0.473	2.237E-01	3.486E-01	1.022E-01	1.394E-01	1.362E-01	1.241E+00	6.946E-02	9.603E-01
RATIO=	3.024	2.750E+00	3.279E+00	3.424E+00	3.403E+00	3.920E+00	3.073E+00	3.170E+00	3.576E+00
MEAN =	9.481								
RMS =	0.140	1.485E-01	1.544E-01	5.130E-02	6.182E-02	5.935E-02	6.916E-01	3.869E-02	4.462E-01
MAX =	0.475	4.108E-01	5.240E-01	1.423E-01	1.816E-01	2.352E-01	1.862E+00	1.221E-01	1.467E+00
RATIO=	3.393	2.767E+00	3.393E+00	2.775E+00	2.937E+00	3.963E+00	2.692E+00	3.157E+00	3.287E+00
MEAN =	10.271								
RMS =	0.125	1.837E-01	2.178E-01	6.434E-02	7.861E-02	7.436E-02	8.667E-01	4.805E-02	5.609E-01
MAX =	0.295	5.874E-01	7.833E-01	2.257E-01	2.746E-01	3.156E-01	2.570E+00	1.717E-01	2.104E+00
RATIO=	2.365	3.198E+00	3.597E+00	3.508E+00	3.494E+00	4.245E+00	2.965E+00	3.574E+00	3.751E+00

FINAL QUINCY IN HIGH TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	11.061								
RMS =	0.214	1.865E-01	2.532E-01	6.679E-02	8.838E-02	8.141E-02	9.479E-01	5.145E-02	6.121E-01
MAX =	0.604	4.915E-01	7.329E-01	1.984E-01	2.569E-01	2.528E-01	2.738E+00	1.372E-01	2.115E+00
RATIO=	2.825	2.635E+00	2.895E+00	2.971E+00	2.907E+00	3.105E+00	2.888E+00	2.666E+00	3.455E+00
MEAN =	11.851								
RMS =	0.275	1.983E-01	3.275E-01	7.584E-02	1.117E-01	8.694E-02	1.017E+00	5.490E-02	6.735E-01
MAX =	1.074	7.498E-01	9.394E-01	2.412E-01	3.938E-01	3.011E-01	2.834E+00	1.465E-01	1.850E+00
RATIO=	3.901	3.780E+00	2.868E+00	3.181E+00	3.526E+00	3.463E+00	2.786E+00	2.669E+00	2.747E+00
MEAN =	12.641								
RMS =	0.257	2.461E-01	3.711E-01	8.571E-02	1.190E-01	9.719E-02	1.142E+00	6.417E-02	7.540E-01
MAX =	0.976	9.682E-01	1.009E+00	3.559E-01	3.636E-01	4.414E-01	3.832E+00	3.147E-01	2.910E+00
RATIO=	3.804	3.934E+00	2.718E+00	4.152E+00	3.056E+00	4.541E+00	3.355E+00	4.904E+00	3.859E+00
MEAN =	13.431								
RMS =	0.196	2.673E-01	5.107E-01	1.003E-01	1.631E-01	1.108E-01	1.299E+00	7.189E-02	8.543E-01
MAX =	0.699	1.059E+00	1.246E+00	3.752E-01	5.331E-01	3.949E-01	3.649E+00	2.294E-01	2.952E+00
RATIO=	3.571	3.960E+00	2.440E+00	3.739E+00	3.270E+00	3.565E+00	2.808E+00	3.191E+00	3.455E+00
MEAN =	14.221								
RMS =	0.199	3.249E-01	5.336E-01	1.142E-01	1.891E-01	1.347E-01	1.580E+00	1.140E-01	1.286E+00
MAX =	0.854	1.039E+00	1.718E+00	4.179E-01	1.084E+00	4.037E-01	4.684E+00	1.387E+00	3.115E+00
RATIO=	4.284	3.198E+00	3.219E+00	3.659E+00	5.732E+00	2.997E+00	2.964E+00	1.217E+01	2.422E+00

ANNACIS IN SMOOTH FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	CENTER TOR(DEG.)	S.CENTER BND(CM)	S.CENTER TOR(DEG.)	N.CENTER BND(CM)	N.CENTER TOR(DEG.)	SIDE SPAN BND(CM)	SIDE SPAN TOR(DEG.)
MEAN =	3.345								
RMS =	0.079	4.794E-03	9.277E-03	4.496E-03	1.244E-02	6.937E-03	8.213E-02	4.949E-03	1.635E-01
MAX =	0.241	1.695E-02	2.656E-02	1.035E-02	2.679E-02	1.438E-02	1.649E-01	9.824E-03	2.786E-01
RATIO=	3.052	3.535E+00	2.864E+00	2.303E+00	2.153E+00	2.073E+00	2.008E+00	1.985E+00	1.704E+00
MEAN =	3.478								
RMS =	0.089	4.852E-03	9.202E-03	4.574E-03	1.250E-02	7.052E-03	8.341E-02	5.091E-03	1.680E-01
MAX =	0.281	1.337E-02	2.556E-02	1.006E-02	2.485E-02	1.429E-02	1.674E-01	9.570E-03	2.790E-01
RATIO=	3.151	2.755E+00	2.778E+00	2.198E+00	1.988E+00	2.026E+00	2.006E+00	1.880E+00	1.661E+00

ANNACIS IN LOW TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	7.033								
RMS =	0.093	3.175E-02	2.788E-02	1.068E-02	1.693E-02	1.231E-02	1.428E-01	7.754E-03	1.027E-01
MAX =	0.421	8.051E-02	8.835E-02	3.212E-02	5.355E-02	3.542E-02	4.040E-01	2.349E-02	3.087E-01
RATIO=	4.542	2.536E+00	3.169E+00	3.007E+00	3.162E+00	2.877E+00	2.828E+00	3.029E+00	3.006E+00
MEAN =	7.890								
RMS =	0.080	3.868E-02	4.051E-02	1.352E-02	1.937E-02	1.596E-02	1.848E-01	9.819E-03	1.336E-01
MAX =	0.239	1.183E-01	1.258E-01	4.581E-02	6.470E-02	5.414E-02	5.436E-01	2.868E-02	3.978E-01
RATIO=	2.984	3.057E+00	3.097E+00	3.389E+00	3.340E+00	3.392E+00	2.941E+00	2.921E+00	2.978E+00
MEAN =	8.669								
RMS =	0.112	4.607E-02	5.009E-02	1.712E-02	2.402E-02	1.996E-02	2.320E-01	1.234E-02	1.665E-01
MAX =	0.237	1.500E-01	1.680E-01	6.357E-02	9.142E-02	6.756E-02	7.227E-01	4.358E-02	5.753E-01
RATIO=	2.110	3.257E+00	3.355E+00	3.714E+00	3.807E+00	3.384E+00	3.116E+00	3.531E+00	3.456E+00
MEAN =	9.632								
RMS =	0.085	7.717E-02	7.053E-02	2.432E-02	2.849E-02	2.855E-02	3.314E-01	1.812E-02	2.267E-01
MAX =	0.248	2.276E-01	2.530E-01	7.659E-02	9.125E-02	9.062E-02	1.077E+00	5.874E-02	7.664E-01
RATIO=	2.916	2.949E+00	3.588E+00	3.149E+00	3.203E+00	3.174E+00	3.250E+00	3.241E+00	3.380E+00
MEAN =	10.596								
RMS =	0.234	7.441E-02	7.730E-02	2.387E-02	3.269E-02	2.861E-02	3.316E-01	1.796E-02	2.359E-01
MAX =	0.460	1.870E-01	2.384E-01	7.073E-02	1.161E-01	9.917E-02	9.240E-01	5.376E-02	6.533E-01
RATIO=	1.962	2.513E+00	3.084E+00	2.963E+00	3.553E+00	3.466E+00	2.787E+00	2.994E+00	2.769E+00
MEAN =	11.559								
RMS =	0.084	9.965E-02	9.853E-02	3.187E-02	3.864E-02	3.561E-02	4.132E-01	2.259E-02	2.830E-01
MAX =	0.389	3.358E-01	3.181E-01	1.089E-01	1.175E-01	1.119E-01	1.136E+00	6.725E-02	1.020E+00
RATIO=	4.608	3.370E+00	3.228E+00	3.415E+00	3.040E+00	3.142E+00	2.750E+00	2.977E+00	3.603E+00
MEAN =	12.522								
RMS =	0.097	1.066E-01	1.215E-01	3.370E-02	4.201E-02	4.016E-02	4.679E-01	2.498E-02	3.310E-01
MAX =	0.418	3.487E-01	4.057E-01	1.135E-01	1.141E-01	1.171E-01	1.302E+00	6.438E-02	1.000E+00
RATIO=	4.299	3.272E+00	3.340E+00	3.368E+00	2.717E+00	2.916E+00	2.783E+00	2.577E+00	3.022E+00
MEAN =	13.485								
RMS =	0.106	1.037E-01	1.548E-01	3.693E-02	5.302E-02	4.033E-02	4.695E-01	2.458E-02	3.343E-01
MAX =	0.601	3.841E-01	5.108E-01	1.272E-01	1.600E-01	1.295E-01	1.370E+00	7.292E-02	1.340E+00
RATIO=	5.667	3.705E+00	3.300E+00	3.443E+00	3.018E+00	3.212E+00	2.917E+00	2.966E+00	4.008E+00
MEAN =	14.448								
RMS =	0.096	1.269E-01	1.833E-01	4.534E-02	6.217E-02	5.007E-02	5.852E-01	3.119E-02	4.045E-01
MAX =	0.575	3.457E-01	5.802E-01	1.546E-01	2.299E-01	1.494E-01	1.600E+00	9.963E-02	1.337E+00
RATIO=	6.001	2.725E+00	3.166E+00	3.411E+00	3.698E+00	2.984E+00	2.734E+00	3.194E+00	3.304E+00
MEAN =	15.412								
RMS =	0.100	9.437E-02	1.950E-01	4.114E-02	7.013E-02	4.727E-02	5.524E-01	2.744E-02	4.103E-01
MAX =	0.495	3.236E-01	5.744E-01	1.391E-01	2.220E-01	1.543E-01	1.645E+00	8.279E-02	1.285E+00
RATIO=	4.941	3.429E+00	2.945E+00	3.381E+00	3.165E+00	3.265E+00	2.978E+00	3.017E+00	3.131E+00

ANNACIS IN HIGH TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	1.579								
RMS =	0.082	2.708E-03	3.187E-03	9.337E-04	1.519E-02	8.991E-04	1.109E-02	6.232E-04	7.330E-03
MAX =	0.216	7.196E-03	8.946E-03	3.357E-03	3.490E-02	2.559E-03	3.398E-02	1.790E-03	2.499E-02
RATIO=	2.622	2.657E+00	2.807E+00	3.595E+00	2.298E+00	2.846E+00	3.062E+00	2.872E+00	3.409E+00
MEAN =	3.291								
RMS =	0.109	1.136E-02	1.327E-02	3.820E-03	3.138E-02	4.369E-03	5.266E-02	2.894E-03	3.560E-02
MAX =	0.379	3.941E-02	3.388E-02	9.350E-03	9.411E-02	1.357E-02	1.626E-01	9.951E-03	1.072E-01
RATIO=	3.471	3.469E+00	2.554E+00	2.447E+00	2.999E+00	3.106E+00	3.088E+00	3.439E+00	3.012E+00
MEAN =	4.175								
RMS =	0.097	1.857E-02	2.078E-02	5.567E-03	4.063E-02	6.588E-03	7.912E-02	4.352E-03	5.303E-02
MAX =	0.255	6.350E-02	5.951E-02	1.522E-02	1.163E-01	2.493E-02	2.938E-01	1.441E-02	1.754E-01
RATIO=	2.519	3.420E+00	2.863E+00	2.734E+00	2.862E+00	3.784E+00	3.713E+00	3.312E+00	3.307E+00
MEAN =	5.098								
RMS =	0.077	3.052E-02	3.471E-02	9.370E-03	7.077E-02	1.096E-02	1.319E-01	7.094E-03	8.561E-02
MAX =	0.265	9.392E-02	1.270E-01	3.037E-02	2.494E-01	3.472E-02	4.634E-01	2.760E-02	2.180E-01
RATIO=	3.444	3.077E+00	3.660E+00	3.241E+00	3.524E+00	3.167E+00	3.512E+00	3.891E+00	2.546E+00
MEAN =	5.605								
RMS =	0.146	4.679E-02	4.192E-02	1.440E-02	1.056E-01	1.683E-02	2.022E-01	1.077E-02	1.308E-01
MAX =	0.480	1.364E-01	1.368E-01	4.788E-02	3.568E-01	5.251E-02	7.277E-01	3.360E-02	3.475E-01
RATIO=	3.284	2.915E+00	3.263E+00	3.325E+00	3.379E+00	3.119E+00	3.599E+00	3.120E+00	2.657E+00
MEAN =	6.251								
RMS =	0.143	6.193E-02	5.811E-02	1.993E-02	1.406E-01	2.344E-02	2.819E-01	1.544E-02	1.850E-01
MAX =	0.468	2.156E-01	1.775E-01	5.918E-02	4.671E-01	7.330E-02	1.168E+00	5.623E-02	6.271E-01
RATIO=	3.275	3.481E+00	3.055E+00	2.969E+00	3.322E+00	3.127E+00	4.145E+00	3.642E+00	3.389E+00
MEAN =	7.220								
RMS =	0.080	6.767E-02	7.137E-02	2.456E-02	1.742E-01	2.991E-02	3.594E-01	1.964E-02	2.475E-01
MAX =	0.237	2.046E-01	2.289E-01	8.818E-02	6.721E-01	1.266E-01	1.249E+00	5.478E-02	9.510E-01
RATIO=	2.968	3.023E+00	3.207E+00	3.590E+00	3.859E+00	4.233E+00	3.476E+00	2.789E+00	3.843E+00
MEAN =	7.724								
RMS =	0.105	8.495E-02	8.999E-02	2.792E-02	2.081E-01	3.322E-02	3.984E-01	2.129E-02	2.765E-01
MAX =	0.338	2.420E-01	2.516E-01	9.648E-02	5.939E-01	8.521E-02	1.353E+00	7.582E-02	7.796E-01
RATIO=	3.204	2.849E+00	2.796E+00	3.455E+00	2.854E+00	2.565E+00	3.397E+00	3.561E+00	2.820E+00

PLATE GIRDER IN SMOOTH FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	CENTER TOR(DEG.)	S.CENTER BND(CM)	S.CENTER TOR(DEG.)	N.CENTER BND(CM)	N.CENTER TOR(DEG.)	SIDE SPAN BND(CM)	SIDE SPAN TOR(DEG.)
MEAN =	1.964								
RMS =	0.078	5.863E-03	6.110E-03	4.104E-02	1.550E-02	5.080E-02	6.026E-01	3.170E-02	4.151E-01
MAX =	0.199	1.267E-02	1.707E-02	6.294E-02	3.600E-02	7.877E-02	8.585E-01	4.706E-02	6.173E-01
RATIO=	2.546	2.161E+00	2.793E+00	1.534E+00	2.323E+00	1.550E+00	1.425E+00	1.484E+00	1.487E+00
MEAN =	1.702								
RMS =	0.095	4.874E-03	4.522E-03	3.531E-02	1.536E-02	4.377E-02	5.195E-01	2.722E-02	3.571E-01
MAX =	0.344	1.119E-02	1.434E-02	5.801E-02	3.699E-02	7.177E-02	7.916E-01	4.249E-02	5.741E-01
RATIO=	3.618	2.297E+00	3.172E+00	1.643E+00	2.409E+00	1.640E+00	1.524E+00	1.561E+00	1.608E+00
MEAN =	1.720								
RMS =	0.073	6.556E-03	4.604E-03	3.702E-02	1.593E-02	4.620E-02	5.483E-01	2.888E-02	3.764E-01
MAX =	0.221	1.434E-02	1.170E-02	5.323E-02	3.433E-02	6.612E-02	7.604E-01	4.414E-02	5.323E-01
RATIO=	3.034	2.187E+00	2.541E+00	1.438E+00	2.155E+00	1.431E+00	1.387E+00	1.528E+00	1.414E+00
MEAN =	1.624								
RMS =	0.077	3.579E-03	3.328E-03	1.967E-02	1.241E-02	2.457E-02	2.920E-01	1.527E-02	1.995E-01
MAX =	0.207	7.931E-03	9.549E-03	3.031E-02	2.597E-02	3.758E-02	4.428E-01	2.444E-02	2.980E-01
RATIO=	2.694	2.216E+00	2.869E+00	1.541E+00	2.092E+00	1.529E+00	1.517E+00	1.600E+00	1.494E+00
MEAN =	1.324								
RMS =	0.074	8.860E-02	1.875E-02	2.326E-02	1.273E-02	2.617E-02	3.108E-01	1.831E-02	1.693E-01
MAX =	0.195	1.407E-01	3.484E-02	3.648E-02	2.922E-02	4.182E-02	4.950E-01	2.904E-02	2.690E-01
RATIO=	2.625	1.588E+00	1.858E+00	1.568E+00	2.296E+00	1.598E+00	1.593E+00	1.587E+00	1.589E+00
MEAN =	1.248								
RMS =	0.078	7.814E-02	1.634E-02	2.055E-02	1.195E-02	2.300E-02	2.732E-01	1.621E-02	1.501E-01
MAX =	0.223	1.234E-01	3.062E-02	3.258E-02	2.734E-02	3.596E-02	4.341E-01	2.660E-02	2.301E-01
RATIO=	2.863	1.580E+00	1.874E+00	1.585E+00	2.287E+00	1.563E+00	1.589E+00	1.641E+00	1.533E+00
MEAN =	1.426								
RMS =	0.081	4.390E-02	8.913E-03	1.149E-02	1.180E-02	1.293E-02	1.536E-01	9.531E-03	8.732E-02
MAX =	0.232	6.764E-02	1.676E-02	1.828E-02	2.267E-02	2.058E-02	2.352E-01	1.864E-02	1.460E-01
RATIO=	2.860	1.541E+00	1.880E+00	1.591E+00	1.922E+00	1.592E+00	1.532E+00	1.955E+00	1.672E+00
MEAN =	3.509								
RMS =	0.078	4.995E-03	5.137E-02	2.075E-02	2.316E-02	3.260E-02	3.948E-01	2.617E-02	7.596E-01
MAX =	0.243	1.532E-02	1.185E-01	3.444E-02	5.401E-02	5.090E-02	6.161E-01	4.015E-02	1.180E+00
RATIO=	3.123	3.068E+00	2.307E+00	1.660E+00	2.333E+00	1.561E+00	1.560E+00	1.534E+00	1.554E+00
MEAN =	4.205								
RMS =	0.075	4.174E-02	1.869E-02	3.522E-02	2.193E-02	4.415E-02	5.293E-01	4.398E-03	1.620E-01
MAX =	0.227	7.572E-02	5.754E-02	5.901E-02	4.505E-02	6.954E-02	8.527E-01	1.049E-02	3.099E-01
RATIO=	3.009	1.814E+00	3.078E+00	1.675E+00	2.054E+00	1.575E+00	1.611E+00	2.385E+00	1.913E+00
MEAN =	4.304								
RMS =	0.075	4.547E-02	1.904E-02	3.836E-02	2.336E-02	4.785E-02	5.735E-01	4.871E-03	1.758E-01
MAX =	0.225	8.694E-02	6.318E-02	6.822E-02	4.900E-02	8.255E-02	1.006E+00	1.106E-02	3.245E-01
RATIO=	2.981	1.912E+00	3.317E+00	1.778E+00	2.098E+00	1.725E+00	1.754E+00	2.270E+00	1.846E+00

PLATE GIRDER IN SMOOTH FLOW

	WIND SPEED	CENTER		S.CENTER		N.CENTER		SIDE SPAN	
	(M/SEC)	BND(CM)	TOR(DEG.)	BND(CM)	TOR(DEG.)	BND(CM)	TOR(DEG.)	BND(CM)	TOR(DEG.)
MEAN =	3.978								
RMS =	0.080	7.186E-03	6.027E-02	1.396E-02	2.100E-02	2.330E-02	2.858E-01	1.702E-02	5.047E-01
MAX =	0.238	2.206E-02	1.698E-01	2.816E-02	6.023E-02	4.243E-02	5.394E-01	3.026E-02	7.881E-01
RATIO=	2.996	3.070E+00	2.818E+00	2.018E+00	2.868E+00	1.821E+00	1.887E+00	1.777E+00	1.561E+00
MEAN =	2.832								
RMS =	0.076	3.362E-03	4.227E-03	1.216E-03	1.103E-02	1.366E-03	1.643E-02	9.658E-04	1.437E-02
MAX =	0.226	9.073E-03	1.283E-02	5.044E-03	2.017E-02	4.576E-03	4.731E-02	3.401E-03	5.111E-02
RATIO=	2.968	2.699E+00	3.034E+00	4.147E+00	1.829E+00	3.350E+00	2.880E+00	3.522E+00	3.557E+00
MEAN =	13.773								
RMS =	0.080	3.644E-02	1.089E-01	1.900E-02	3.784E-02	2.276E-02	2.735E-01	1.213E-02	1.976E-01
MAX =	0.430	1.268E-01	2.281E-01	5.432E-02	1.066E-01	6.265E-02	1.204E+00	4.473E-02	6.545E-01
RATIO=	5.357	3.481E+00	2.095E+00	2.859E+00	2.816E+00	2.752E+00	4.403E+00	3.688E+00	3.312E+00
MEAN =	14.920								
RMS =	0.077	4.567E-02	2.916E-01	2.011E-02	8.162E-02	2.418E-02	2.936E-01	1.233E-02	2.272E-01
MAX =	0.213	1.500E-01	6.716E-01	5.690E-02	2.005E-01	8.115E-02	9.749E-01	3.934E-02	7.453E-01
RATIO=	2.754	3.284E+00	2.303E+00	2.829E+00	2.457E+00	3.356E+00	3.320E+00	3.189E+00	3.281E+00
MEAN =	15.150								
RMS =	0.087	4.613E-02	4.466E-01	2.147E-02	1.195E-01	2.585E-02	3.228E-01	1.382E-02	2.309E-01
MAX =	0.474	1.758E-01	7.757E-01	6.406E-02	2.606E-01	9.113E-02	1.052E+00	4.158E-02	6.987E-01
RATIO=	5.446	3.811E+00	1.737E+00	2.983E+00	2.181E+00	3.525E+00	3.258E+00	3.008E+00	3.026E+00
MEAN =	15.609								
RMS =	0.086	5.596E-02	7.119E-01	2.302E-02	1.884E-01	2.627E-02	3.534E-01	1.443E-02	2.650E-01
MAX =	0.522	1.822E-01	1.405E+00	6.957E-02	3.925E-01	7.756E-02	1.380E+00	4.780E-02	8.858E-01
RATIO=	6.101	3.256E+00	1.973E+00	3.023E+00	2.083E+00	2.952E+00	3.904E+00	3.312E+00	3.342E+00
MEAN =	15.839								
RMS =	0.082	6.025E-02	1.050E+00	2.351E-02	2.767E-01	2.856E-02	4.088E-01	1.606E-02	3.191E-01
MAX =	0.519	1.824E-01	1.704E+00	9.845E-02	5.137E-01	7.688E-02	1.295E+00	5.483E-02	9.323E-01
RATIO=	6.341	3.028E+00	1.623E+00	4.187E+00	1.856E+00	2.692E+00	3.167E+00	3.413E+00	2.922E+00

PLATE GIRDER IN LOW TURBULENT FLOW

	WIND SPEED	CENTER		S. CENTER		N. CENTER		SIDE SPAN	
	(M/SEC)	BND(CM)	TOR(DEG.)	BND(CM)	TOR(DEG.)	BND(CM)	TOR(DEG.)	BND(CM)	TOR(DEG.)
MEAN =	1.536								
RMS =	0.082	1.974E-02	3.453E-03	5.040E-03	1.180E-02	5.722E-03	6.716E-02	4.034E-03	3.854E-02
MAX =	0.230	3.274E-02	1.433E-02	8.724E-03	2.188E-02	1.034E-02	1.130E-01	6.888E-03	7.213E-02
RATIO=	2.819	1.659E+00	4.151E+00	1.731E+00	1.855E+00	1.807E+00	1.682E+00	1.708E+00	1.872E+00
MEAN =	1.635								
RMS =	0.086	3.993E-03	2.890E-03	2.479E-02	1.452E-02	2.959E-02	3.464E-01	1.866E-02	2.459E-01
MAX =	0.241	9.901E-03	8.338E-03	3.910E-02	2.826E-02	4.780E-02	5.279E-01	2.953E-02	3.870E-01
RATIO=	2.818	2.479E+00	2.885E+00	1.577E+00	1.946E+00	1.615E+00	1.524E+00	1.582E+00	1.574E+00
MEAN =	7.706								
RMS =	0.085	5.464E-02	7.966E-02	1.353E-02	2.978E-02	2.171E-02	2.563E-01	1.402E-02	1.761E-01
MAX =	0.265	1.630E-01	2.112E-01	5.075E-02	7.782E-02	7.117E-02	6.685E-01	4.506E-02	5.147E-01
RATIO=	3.124	2.984E+00	2.651E+00	2.739E+00	2.613E+00	3.278E+00	2.609E+00	3.214E+00	2.923E+00
MEAN =	9.632								
RMS =	0.081	7.311E-02	1.193E-01	3.002E-02	4.403E-02	3.411E-02	4.015E-01	2.105E-02	2.805E-01
MAX =	0.297	2.068E-01	3.396E-01	9.838E-02	1.460E-01	1.267E-01	1.240E+00	6.272E-02	1.227E+00
RATIO=	3.639	2.828E+00	2.846E+00	3.277E+00	3.316E+00	3.716E+00	3.089E+00	2.979E+00	4.374E+00
MEAN =	10.596								
RMS =	0.110	9.628E-02	1.404E-01	3.549E-02	5.091E-02	4.054E-02	4.782E-01	2.532E-02	3.256E-01
MAX =	0.474	3.936E-01	3.866E-01	1.249E-01	1.476E-01	1.493E-01	1.641E+00	9.446E-02	1.422E+00
RATIO=	4.328	4.088E+00	2.755E+00	3.520E+00	2.899E+00	3.682E+00	3.431E+00	3.731E+00	4.367E+00
MEAN =	11.559								
RMS =	0.112	1.015E-01	1.657E-01	3.954E-02	5.685E-02	4.704E-02	5.534E-01	2.949E-02	3.848E-01
MAX =	0.437	3.031E-01	3.994E-01	1.161E-01	1.755E-01	1.580E-01	1.778E+00	9.677E-02	1.136E+00
RATIO=	3.892	2.985E+00	2.411E+00	2.936E+00	3.088E+00	3.359E+00	3.213E+00	3.281E+00	2.951E+00
MEAN =	12.522								
RMS =	0.103	1.039E-01	1.908E-01	4.204E-02	6.572E-02	5.026E-02	5.922E-01	3.079E-02	4.289E-01
MAX =	0.507	3.286E-01	5.905E-01	1.415E-01	1.892E-01	1.725E-01	1.857E+00	9.711E-02	1.354E+00
RATIO=	4.926	3.163E+00	3.096E+00	3.366E+00	2.880E+00	3.432E+00	3.135E+00	3.154E+00	3.156E+00
MEAN =	13.485								
RMS =	0.104	1.189E-01	4.359E-01	4.858E-02	1.242E-01	5.584E-02	6.594E-01	3.396E-02	4.902E-01
MAX =	0.714	3.375E-01	9.491E-01	1.529E-01	2.995E-01	2.213E-01	2.109E+00	1.144E-01	1.501E+00
RATIO=	6.865	2.838E+00	2.178E+00	3.147E+00	2.412E+00	3.963E+00	3.199E+00	3.369E+00	3.061E+00
MEAN =	14.448								
RMS =	0.127	1.511E-01	4.902E-01	5.710E-02	1.395E-01	6.487E-02	7.804E-01	3.993E-02	5.305E-01
MAX =	0.608	5.140E-01	1.604E+00	2.026E-01	3.997E-01	2.308E-01	2.205E+00	1.148E-01	2.055E+00
RATIO=	4.787	3.403E+00	3.271E+00	3.549E+00	2.866E+00	3.557E+00	2.826E+00	2.874E+00	3.874E+00
MEAN =	15.412								
RMS =	0.100	1.512E-01	1.275E+00	5.882E-02	3.500E-01	6.919E-02	8.783E-01	4.061E-02	5.589E-01
MAX =	0.648	5.206E-01	2.513E+00	2.050E-01	1.086E+00	2.275E-01	2.280E+00	1.618E-01	2.396E+00
RATIO=	6.456	3.442E+00	1.970E+00	3.486E+00	3.102E+00	3.289E+00	2.596E+00	3.985E+00	4.287E+00

PLATE GIRDER IN HIGH TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	3.277								
RMS =	0.087	1.761E-02	1.312E-02	5.156E-03	2.700E-02	2.757E-03	2.575E-03	4.158E-03	4.951E-02
MAX =	0.278	4.354E-02	3.886E-02	1.460E-02	4.289E-02	8.112E-03	8.068E-03	1.063E-02	1.627E-01
RATIO=	3.206	2.472E+00	2.953E+00	2.832E+00	1.589E+00	2.942E+00	3.134E+00	2.557E+00	3.286E+00
MEAN =	3.855								
RMS =	0.103	2.183E-02	4.041E-02	7.993E-03	2.472E-02	4.551E-03	6.163E-03	6.055E-03	7.934E-02
MAX =	0.271	6.142E-02	1.020E-01	2.341E-02	5.145E-02	1.497E-02	1.852E-02	1.642E-02	2.356E-01
RATIO=	2.635	2.814E+00	2.523E+00	2.929E+00	2.081E+00	3.289E+00	3.006E+00	2.711E+00	2.969E+00
MEAN =	4.780								
RMS =	0.161	3.639E-02	2.912E-02	1.215E-02	2.424E-02	6.538E-03	5.769E-03	9.069E-03	1.028E-01
MAX =	0.389	1.521E-01	7.897E-02	5.381E-02	6.221E-02	2.112E-02	1.855E-02	2.969E-02	3.139E-01
RATIO=	2.412	4.180E+00	2.712E+00	4.428E+00	2.566E+00	3.230E+00	3.216E+00	3.273E+00	3.052E+00
MEAN =	5.535								
RMS =	0.153	5.168E-02	5.414E-02	1.801E-02	2.820E-02	9.970E-03	1.013E-02	1.366E-02	1.665E-01
MAX =	0.361	1.492E-01	1.351E-01	5.631E-02	8.186E-02	3.200E-02	3.265E-02	4.245E-02	5.353E-01
RATIO=	2.359	2.887E+00	2.495E+00	3.127E+00	2.903E+00	3.209E+00	3.221E+00	3.107E+00	3.214E+00
MEAN =	6.224								
RMS =	0.143	5.939E-02	6.999E-02	2.417E-02	3.588E-02	1.337E-02	1.329E-02	1.785E-02	2.156E-01
MAX =	0.341	1.770E-01	1.814E-01	6.995E-02	9.531E-02	3.798E-02	4.146E-02	6.251E-02	6.812E-01
RATIO=	2.386	2.980E+00	2.591E+00	2.894E+00	2.657E+00	2.842E+00	3.119E+00	3.501E+00	3.160E+00
MEAN =	7.146								
RMS =	0.144	1.010E-01	7.005E-02	3.414E-02	3.661E-02	1.906E-02	1.594E-02	2.639E-02	3.012E-01
MAX =	0.546	3.546E-01	2.036E-01	1.080E-01	1.072E-01	6.258E-02	5.393E-02	8.032E-02	8.791E-01
RATIO=	3.795	3.512E+00	2.907E+00	3.163E+00	2.928E+00	3.283E+00	3.384E+00	3.043E+00	2.918E+00
MEAN =	7.901								
RMS =	0.150	1.202E-01	8.992E-02	4.111E-02	4.131E-02	2.220E-02	2.030E-02	3.075E-02	3.540E-01
MAX =	0.273	3.912E-01	2.496E-01	1.416E-01	1.148E-01	7.032E-02	8.445E-02	1.158E-01	1.194E+00
RATIO=	2.477	3.256E+00	2.776E+00	3.445E+00	2.779E+00	3.167E+00	4.161E+00	3.765E+00	3.372E+00

PLATE GIRDER WITH FAIRINGS IN SMOOTH FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	1.632								
RMS =	0.337	5.918E-03	1.619E-01	3.493E-02	3.855E-01	4.004E-02	5.905E-01	2.314E-02	3.301E-01
MAX =	0.240	2.993E-02	2.116E+00	3.133E-01	1.761E-01	1.836E-01	6.207E+00	5.030E-02	2.140E+00
RATIO=	0.712	5.057E+00	1.307E+01	8.970E+00	4.567E-01	4.584E+00	1.051E+01	2.174E+00	6.484E+00
MEAN =	1.334								
RMS =	0.148	3.722E-03	2.802E-03	2.043E-02	1.470E-02	2.381E-02	2.761E-01	1.475E-02	1.950E-01
MAX =	0.330	1.242E-02	8.296E-03	3.695E-02	3.265E-02	4.334E-02	4.686E-01	2.657E-02	3.441E-01
RATIO=	2.232	3.336E+00	2.961E+00	1.809E+00	2.221E+00	1.820E+00	1.697E+00	1.801E+00	1.764E+00
MEAN =	4.217								
RMS =	0.069	3.243E-02	5.890E-02	2.755E-02	2.805E-02	3.225E-02	3.763E-01	4.338E-03	1.348E-01
MAX =	0.228	7.665E-02	1.805E-01	5.597E-02	6.662E-02	7.232E-02	7.882E-01	1.339E-02	3.118E-01
RATIO=	3.292	2.363E+00	3.064E+00	2.031E+00	2.375E+00	2.242E+00	2.095E+00	3.087E+00	2.313E+00
MEAN =	7.069								
RMS =	0.209	2.515E-02	3.853E-02	1.081E-02	2.223E-02	1.165E-02	1.368E-01	6.589E-03	9.383E-02
MAX =	0.662	7.986E-02	1.094E-01	3.368E-02	6.390E-02	3.251E-02	4.223E-01	1.765E-02	2.706E-01
RATIO=	3.168	3.175E+00	2.840E+00	3.116E+00	2.875E+00	2.791E+00	3.088E+00	2.678E+00	2.884E+00
MEAN =	8.921								
RMS =	0.093	2.580E-02	5.137E-02	1.296E-02	3.213E-02	1.516E-02	1.776E-01	8.553E-03	1.326E-01
MAX =	0.310	7.170E-02	1.304E-01	3.586E-02	1.176E-01	4.096E-02	5.392E-01	2.682E-02	5.315E-01
RATIO=	3.348	2.779E+00	2.538E+00	2.766E+00	3.661E+00	2.701E+00	3.036E+00	3.136E+00	4.008E+00
MEAN =	12.625								
RMS =	0.114	3.996E-02	9.816E-02	1.829E-02	4.170E-02	2.040E-02	2.393E-01	1.186E-02	1.834E-01
MAX =	0.391	1.052E-01	2.874E-01	6.956E-02	1.210E-01	6.066E-02	7.191E-01	3.541E-02	5.417E-01
RATIO=	3.423	2.633E+00	2.928E+00	3.804E+00	2.902E+00	2.974E+00	3.005E+00	2.986E+00	2.954E+00
MEAN =	13.773								
RMS =	0.080	3.888E-02	1.077E-01	1.973E-02	4.487E-02	2.110E-02	2.479E-01	1.158E-02	1.961E-01
MAX =	0.339	1.173E-01	2.890E-01	6.260E-02	1.389E-01	6.553E-02	7.383E-01	3.450E-02	6.324E-01
RATIO=	4.980	3.016E+00	2.683E+00	3.173E+00	3.096E+00	3.106E+00	2.978E+00	2.980E+00	3.224E+00
MEAN =	14.920								
RMS =	0.092	5.148E-02	1.219E-01	2.357E-02	4.974E-02	2.620E-02	3.084E-01	1.486E-02	2.408E-01
MAX =	0.442	1.829E-01	3.235E-01	7.624E-02	1.764E-01	8.899E-02	9.752E-01	4.682E-02	8.876E-01
RATIO=	4.820	3.553E+00	2.654E+00	3.235E+00	3.546E+00	3.397E+00	3.162E+00	3.152E+00	3.687E+00
MEAN =	15.609								
RMS =	0.134	5.488E-02	2.537E-01	2.430E-02	7.746E-02	2.764E-02	3.261E-01	1.515E-02	2.485E-01
MAX =	0.467	1.842E-01	5.540E-01	7.335E-02	2.409E-01	1.057E-01	1.043E+00	4.619E-02	6.998E-01
RATIO=	3.496	3.356E+00	2.184E+00	3.019E+00	3.110E+00	3.823E+00	3.197E+00	3.050E+00	2.815E+00
MEAN =	16.527								
RMS =	0.089	6.358E-02	5.026E-01	2.515E-02	1.397E-01	2.845E-02	3.463E-01	1.563E-02	2.542E-01
MAX =	0.715	1.827E-01	9.301E-01	7.314E-02	3.224E-01	8.218E-02	1.032E+00	4.888E-02	8.588E-01
RATIO=	8.064	2.874E+00	1.851E+00	2.908E+00	2.307E+00	2.889E+00	2.979E+00	3.127E+00	3.378E+00

PLATE GIRDER WITH FAIRINGS IN SMOOTH FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	16.757								
RMS =	0.161	1.144E-01	2.764E+00	3.005E-02	7.553E-01	4.369E-02	9.535E-01	1.871E-02	3.685E-01
MAX =	0.496	2.892E-01	4.540E+00	9.381E-02	1.363E+00	1.361E-01	1.987E+00	5.613E-02	1.217E+00
RATIO=	3.084	2.528E+00	1.642E+00	3.122E+00	1.805E+00	3.115E+00	2.084E+00	3.001E+00	3.303E+00

PLATE GIRDER WITH FAIRINGS IN LOW TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	7.640								
RMS =	0.132	5.050E-02	5.064E-02	1.798E-02	2.861E-02	2.049E-02	2.419E-01	1.291E-02	1.622E-01
MAX =	0.524	1.554E-01	1.346E-01	6.476E-02	8.677E-02	8.049E-02	8.206E-01	5.081E-02	6.131E-01
RATIO=	3.982	3.078E+00	2.659E+00	3.601E+00	3.032E+00	3.928E+00	3.392E+00	3.937E+00	3.779E+00
MEAN =	9.632								
RMS =	0.099	6.788E-02	1.184E-01	2.691E-02	4.422E-02	3.101E-02	3.674E-01	1.930E-02	2.597E-01
MAX =	0.270	2.344E-01	3.566E-01	9.060E-02	1.450E-01	9.012E-02	1.413E+00	6.287E-02	8.103E-01
RATIO=	2.721	3.453E+00	3.013E+00	3.367E+00	3.280E+00	2.906E+00	3.845E+00	3.257E+00	3.120E+00
MEAN =	11.559								
RMS =	0.164	1.091E-01	1.340E-01	4.225E-02	5.111E-02	4.684E-02	5.516E-01	2.913E-02	3.878E-01
MAX =	0.644	2.791E-01	4.139E-01	1.546E-01	1.658E-01	1.402E-01	1.584E+00	8.855E-02	1.296E+00
RATIO=	3.930	2.557E+00	3.088E+00	3.658E+00	3.264E+00	2.994E+00	2.871E+00	3.040E+00	3.342E+00
MEAN =	12.522								
RMS =	0.106	1.272E-01	1.836E-01	4.577E-02	6.286E-02	5.519E-02	6.513E-01	3.471E-02	4.482E-01
MAX =	0.644	4.068E-01	5.624E-01	1.344E-01	2.265E-01	1.797E-01	2.159E+00	1.232E-01	1.684E+00
RATIO=	6.074	3.197E+00	3.063E+00	2.935E+00	3.604E+00	3.256E+00	3.315E+00	3.549E+00	3.758E+00
MEAN =	13.485								
RMS =	0.108	1.371E-01	2.911E-01	5.292E-02	8.864E-02	5.682E-02	6.764E-01	3.576E-02	4.690E-01
MAX =	0.471	4.623E-01	8.042E-01	1.813E-01	2.662E-01	1.662E-01	1.866E+00	1.095E-01	1.556E+00
RATIO=	4.339	3.373E+00	2.762E+00	3.427E+00	3.003E+00	2.925E+00	2.758E+00	3.062E+00	3.317E+00
MEAN =	14.448								
RMS =	0.137	1.410E-01	3.264E-01	5.421E-02	1.028E-01	6.210E-02	7.359E-01	3.836E-02	5.340E-01
MAX =	0.972	4.647E-01	8.846E-01	2.123E-01	2.731E-01	2.019E-01	2.118E+00	1.213E-01	1.798E+00
RATIO=	7.108	3.296E+00	2.710E+00	3.916E+00	2.657E+00	3.251E+00	2.878E+00	3.162E+00	3.367E+00
MEAN =	15.412								
RMS =	0.185	1.628E-01	4.380E-01	6.173E-02	1.349E-01	7.217E-02	8.600E-01	4.402E-02	5.984E-01
MAX =	0.758	4.340E-01	1.271E+00	2.332E-01	4.282E-01	2.431E-01	2.429E+00	1.237E-01	1.672E+00
RATIO=	4.095	2.665E+00	2.902E+00	3.778E+00	3.175E+00	3.369E+00	2.824E+00	2.810E+00	2.794E+00
MEAN =	16.375								
RMS =	0.183	1.606E-01	7.135E-01	6.472E-02	2.071E-01	7.460E-02	9.104E-01	4.429E-02	6.200E-01
MAX =	2.421	5.691E-01	1.897E+00	1.838E-01	6.067E-01	2.472E-01	2.661E+00	1.595E-01	1.750E+00
RATIO=	13.209	3.544E+00	2.659E+00	2.840E+00	2.929E+00	3.313E+00	2.923E+00	3.601E+00	2.822E+00

PLATE GIRDER WITH FAIRINGS IN HIGH TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	3.173								
RMS =	0.172	1.109E-02	1.135E-02	4.128E-03	2.311E-02	2.128E-03	2.554E-03	2.965E-03	3.684E-02
MAX =	0.421	2.970E-02	3.328E-02	1.490E-02	4.406E-02	7.023E-03	7.800E-03	9.865E-03	1.082E-01
RATIO=	2.452	2.679E+00	2.933E+00	3.610E+00	1.906E+00	3.301E+00	3.054E+00	3.328E+00	2.937E+00
MEAN =	3.901								
RMS =	0.105	2.593E-02	3.787E-02	9.480E-03	2.989E-02	5.003E-03	6.522E-03	6.748E-03	8.111E-02
MAX =	0.279	7.911E-02	9.528E-02	2.772E-02	6.385E-02	1.584E-02	1.688E-02	1.951E-02	2.183E-01
RATIO=	2.658	3.051E+00	2.516E+00	2.924E+00	2.136E+00	3.166E+00	2.587E+00	2.891E+00	2.691E+00
MEAN =	4.934								
RMS =	0.133	4.026E-02	4.689E-02	1.379E-02	3.082E-02	7.583E-03	9.725E-03	9.874E-03	1.129E-01
MAX =	0.333	1.494E-01	1.404E-01	4.868E-02	7.447E-02	2.340E-02	2.966E-02	4.230E-02	3.504E-01
RATIO=	2.513	3.711E+00	2.994E+00	3.529E+00	2.416E+00	3.086E+00	3.050E+00	4.284E+00	3.103E+00
MEAN =	5.663								
RMS =	0.114	4.986E-02	5.316E-02	1.981E-02	3.425E-02	1.056E-02	1.310E-02	1.388E-02	1.656E-01
MAX =	0.349	1.470E-01	1.409E-01	6.553E-02	9.800E-02	3.739E-02	4.339E-02	4.396E-02	6.098E-01
RATIO=	3.059	2.948E+00	2.651E+00	3.307E+00	2.862E+00	3.542E+00	3.312E+00	3.167E+00	3.682E+00
MEAN =	6.393								
RMS =	0.137	5.507E-02	6.543E-02	2.439E-02	3.779E-02	1.349E-02	1.723E-02	1.691E-02	2.126E-01
MAX =	0.454	1.568E-01	1.701E-01	7.203E-02	1.309E-01	3.949E-02	5.369E-02	6.262E-02	6.344E-01
RATIO=	3.303	2.849E+00	2.599E+00	2.953E+00	3.464E+00	2.927E+00	3.115E+00	3.704E+00	2.983E+00
MEAN =	7.236								
RMS =	0.176	7.656E-02	8.267E-02	3.128E-02	4.330E-02	1.709E-02	2.280E-02	2.212E-02	2.787E-01
MAX =	0.405	2.138E-01	2.357E-01	9.728E-02	1.195E-01	6.043E-02	8.413E-02	6.518E-02	7.108E-01
RATIO=	2.303	2.793E+00	2.852E+00	3.110E+00	2.759E+00	3.536E+00	3.690E+00	2.947E+00	2.551E+00
MEAN =	7.901								
RMS =	0.120	1.067E-01	9.924E-02	4.160E-02	5.147E-02	2.213E-02	2.939E-02	2.870E-02	3.478E-01
MAX =	0.376	3.586E-01	2.712E-01	1.524E-01	1.478E-01	6.552E-02	1.079E-01	8.615E-02	1.097E+00
RATIO=	3.125	3.361E+00	2.732E+00	3.663E+00	2.871E+00	2.961E+00	3.670E+00	3.002E+00	3.154E+00

ONE BOX IN SMOOTH FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	CENTER TOR(DEG.)	S.CENTER BND(CM)	S.CENTER TOR(DEG.)	N.CENTER BND(CM)	N.CENTER TOR(DEG.)	SIDE SPAN BND(CM)	SIDE SPAN TOR(DEG.)
MEAN =	3.961								
RMS =	0.077	4.778E-03	1.526E-02	2.085E-03	2.803E-02	2.948E-03	3.489E-02	1.742E-03	4.093E-02
MAX =	0.249	1.557E-02	5.751E-02	6.277E-03	7.819E-02	9.370E-03	1.193E-01	5.197E-03	1.239E-01
RATIO=	3.240	3.259E+00	3.769E+00	3.010E+00	2.790E+00	3.178E+00	3.419E+00	2.984E+00	3.028E+00
MEAN =	6.546								
RMS =	0.075	1.209E-02	2.507E-02	5.382E-03	6.081E-02	7.328E-03	8.735E-02	4.256E-03	5.634E-02
MAX =	0.257	3.764E-02	6.785E-02	1.688E-02	1.965E-01	2.261E-02	2.350E-01	1.229E-02	1.849E-01
RATIO=	3.443	3.114E+00	2.707E+00	3.136E+00	3.231E+00	3.085E+00	2.690E+00	2.887E+00	3.282E+00
MEAN =	11.477								
RMS =	0.069	2.527E-02	6.620E-02	9.827E-03	9.841E-02	1.276E-02	1.532E-01	7.429E-03	1.117E-01
MAX =	0.232	7.269E-02	1.774E-01	2.897E-02	3.416E-01	4.211E-02	4.342E-01	2.432E-02	3.736E-01
RATIO=	3.332	2.877E+00	2.679E+00	2.948E+00	3.471E+00	3.299E+00	2.834E+00	3.274E+00	3.343E+00
MEAN =	15.609								
RMS =	0.089	3.648E-02	1.961E-01	1.462E-02	1.597E-01	1.934E-02	2.370E-01	1.075E-02	1.657E-01
MAX =	0.581	1.149E-01	4.213E-01	4.345E-02	5.183E-01	5.691E-02	7.474E-01	2.875E-02	5.295E-01
RATIO=	6.510	3.150E+00	2.148E+00	2.973E+00	3.245E+00	2.942E+00	3.153E+00	2.675E+00	3.196E+00
MEAN =	16.068								
RMS =	0.092	3.405E-02	1.975E-01	1.511E-02	1.732E-01	2.044E-02	2.471E-01	1.125E-02	1.772E-01
MAX =	0.375	8.698E-02	5.809E-01	5.058E-02	6.774E-01	6.339E-02	7.436E-01	3.178E-02	5.102E-01
RATIO=	4.099	2.554E+00	2.942E+00	3.348E+00	3.912E+00	3.101E+00	3.010E+00	2.824E+00	2.880E+00
MEAN =	17.216								
RMS =	0.086	4.276E-02	9.242E-01	1.703E-02	2.947E-01	2.284E-02	3.730E-01	1.326E-02	2.103E-01
MAX =	0.479	1.245E-01	1.778E+00	4.924E-02	8.084E-01	6.255E-02	1.031E+00	3.934E-02	7.085E-01
RATIO=	5.572	2.912E+00	1.924E+00	2.891E+00	2.743E+00	2.739E+00	2.764E+00	2.967E+00	3.368E+00
MEAN =	16.527								
RMS =	0.080	3.775E-02	2.117E-01	1.491E-02	1.760E-01	2.073E-02	2.548E-01	1.199E-02	1.892E-01
MAX =	0.304	1.230E-01	6.193E-01	4.789E-02	5.729E-01	7.107E-02	7.083E-01	4.003E-02	6.235E-01
RATIO=	3.816	3.258E+00	2.926E+00	3.212E+00	3.255E+00	3.429E+00	2.780E+00	3.338E+00	3.296E+00
MEAN =	16.757								
RMS =	0.083	4.323E-02	2.998E-01	1.638E-02	1.848E-01	2.176E-02	2.690E-01	1.315E-02	1.990E-01
MAX =	0.340	1.503E-01	7.156E-01	4.735E-02	5.135E-01	6.718E-02	7.993E-01	4.428E-02	6.265E-01
RATIO=	4.097	3.477E+00	2.387E+00	2.891E+00	2.778E+00	3.088E+00	2.972E+00	3.366E+00	3.149E+00

ONE BOX IN LOW TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	7.597								
RMS =	0.085	5.048E-02	6.145E-02	1.643E-02	2.317E-02	1.805E-02	2.127E-01	1.210E-02	1.416E-01
MAX =	0.349	1.612E-01	2.149E-01	4.377E-02	6.573E-02	5.315E-02	6.442E-01	3.691E-02	5.129E-01
RATIO=	4.088	3.193E+00	3.497E+00	2.665E+00	2.837E+00	2.944E+00	3.028E+00	3.051E+00	3.621E+00
MEAN =	8.669								
RMS =	0.089	5.166E-02	8.372E-02	1.889E-02	2.903E-02	2.077E-02	2.451E-01	1.342E-02	1.700E-01
MAX =	0.384	1.546E-01	2.246E-01	5.705E-02	9.898E-02	7.396E-02	6.368E-01	4.516E-02	6.598E-01
RATIO=	4.321	2.993E+00	2.683E+00	3.019E+00	3.409E+00	3.560E+00	2.598E+00	3.365E+00	3.880E+00
MEAN =	9.632								
RMS =	0.085	5.876E-02	1.047E-01	2.392E-02	3.746E-02	2.755E-02	3.243E-01	1.780E-02	2.210E-01
MAX =	0.245	1.598E-01	3.379E-01	7.020E-02	1.299E-01	8.267E-02	1.002E+00	5.151E-02	7.928E-01
RATIO=	2.889	2.719E+00	3.227E+00	2.935E+00	3.468E+00	3.000E+00	3.091E+00	2.893E+00	3.587E+00
MEAN =	10.596								
RMS =	0.086	7.103E-02	1.326E-01	2.747E-02	4.503E-02	3.178E-02	3.754E-01	2.047E-02	2.573E-01
MAX =	0.434	2.168E-01	4.409E-01	7.126E-02	1.523E-01	9.582E-02	1.139E+00	6.009E-02	8.476E-01
RATIO=	5.067	3.052E+00	3.324E+00	2.594E+00	3.383E+00	3.015E+00	3.035E+00	2.935E+00	3.295E+00
MEAN =	11.559								
RMS =	0.081	9.035E-02	1.759E-01	3.396E-02	5.535E-02	4.042E-02	4.777E-01	2.618E-02	3.301E-01
MAX =	0.320	2.639E-01	5.137E-01	9.911E-02	1.758E-01	1.243E-01	1.519E+00	8.604E-02	9.427E-01
RATIO=	3.956	2.920E+00	2.920E+00	2.918E+00	3.176E+00	3.075E+00	3.181E+00	3.287E+00	2.855E+00
MEAN =	12.522								
RMS =	0.085	1.002E-01	1.733E-01	3.974E-02	5.864E-02	4.491E-02	5.312E-01	2.917E-02	3.782E-01
MAX =	0.533	2.653E-01	5.696E-01	1.073E-01	1.669E-01	1.253E-01	1.429E+00	8.124E-02	1.145E+00
RATIO=	6.273	2.648E+00	3.286E+00	2.700E+00	2.846E+00	2.790E+00	2.690E+00	2.785E+00	3.028E+00
MEAN =	13.485								
RMS =	0.088	1.131E-01	2.244E-01	4.325E-02	7.444E-02	4.977E-02	5.884E-01	3.145E-02	4.056E-01
MAX =	0.528	3.524E-01	5.766E-01	1.328E-01	2.279E-01	1.518E-01	1.733E+00	9.575E-02	1.301E+00
RATIO=	6.023	3.114E+00	2.569E+00	3.069E+00	3.061E+00	3.050E+00	2.946E+00	3.044E+00	3.207E+00
MEAN =	14.063								
RMS =	0.089	1.195E-01	2.388E-01	4.800E-02	7.962E-02	5.328E-02	6.317E-01	3.305E-02	4.283E-01
MAX =	0.451	3.578E-01	5.684E-01	1.779E-01	2.658E-01	1.782E-01	1.870E+00	1.141E-01	1.342E+00
RATIO=	5.052	2.995E+00	2.380E+00	3.706E+00	3.339E+00	3.344E+00	2.960E+00	3.453E+00	3.133E+00
MEAN =	14.641								
RMS =	0.097	1.322E-01	3.357E-01	5.120E-02	1.088E-01	5.880E-02	6.959E-01	3.808E-02	4.843E-01
MAX =	0.476	3.866E-01	8.763E-01	1.672E-01	3.147E-01	1.718E-01	1.798E+00	9.435E-02	1.833E+00
RATIO=	4.885	2.924E+00	2.610E+00	3.266E+00	2.891E+00	2.921E+00	2.584E+00	2.478E+00	3.785E+00
MEAN =	15.219								
RMS =	0.099	1.225E-01	3.500E-01	4.879E-02	1.115E-01	5.274E-02	6.284E-01	3.420E-02	4.788E-01
MAX =	0.616	4.040E-01	1.231E+00	1.739E-01	5.201E-01	1.597E-01	1.724E+00	1.034E-01	1.450E+00
RATIO=	6.208	3.298E+00	3.516E+00	3.565E+00	4.665E+00	3.028E+00	2.743E+00	3.022E+00	3.029E+00

ONE BOX IN LOW TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	15.797								
RMS =	0.100	1.396E-01	4.097E-01	5.391E-02	1.242E-01	6.249E-02	7.467E-01	3.922E-02	5.213E-01
MAX =	0.588	5.563E-01	1.026E+00	1.813E-01	3.709E-01	2.069E-01	2.204E+00	1.301E-01	1.768E+00
RATIO=	5.886	3.985E+00	2.504E+00	3.362E+00	2.985E+00	3.310E+00	2.952E+00	3.317E+00	3.391E+00
MEAN =	16.375								
RMS =	0.101	1.370E-01	5.468E-01	5.669E-02	1.616E-01	6.854E-02	8.314E-01	4.215E-02	5.549E-01
MAX =	0.756	3.870E-01	1.975E+00	1.691E-01	6.477E-01	2.053E-01	2.698E+00	1.275E-01	1.702E+00
RATIO=	7.490	2.825E+00	3.612E+00	2.983E+00	4.009E+00	2.995E+00	3.245E+00	3.025E+00	3.067E+00

ONE BOX IN HIGH TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	2.348								
RMS =	0.111	6.800E-03	5.190E-03	2.138E-03	1.915E-02	2.387E-03	2.807E-02	1.627E-03	1.536E-02
MAX =	0.297	1.785E-02	1.940E-02	6.956E-03	5.889E-02	6.823E-03	9.214E-02	5.213E-03	4.719E-02
RATIO=	2.666	2.625E+00	3.739E+00	3.254E+00	3.076E+00	2.859E+00	3.283E+00	3.203E+00	3.073E+00
MEAN =	2.478								
RMS =	0.094	7.177E-03	6.070E-03	2.357E-03	1.920E-02	2.497E-03	2.944E-02	1.747E-03	1.805E-02
MAX =	0.282	2.241E-02	1.601E-02	6.685E-03	5.404E-02	7.133E-03	8.636E-02	5.541E-03	5.602E-02
RATIO=	2.988	3.122E+00	2.638E+00	2.836E+00	2.815E+00	2.857E+00	2.934E+00	3.171E+00	3.104E+00
MEAN =	2.570								
RMS =	0.121	1.047E-02	6.983E-03	3.070E-03	2.149E-02	3.393E-03	3.972E-02	2.407E-03	2.415E-02
MAX =	0.354	3.356E-02	2.199E-02	1.028E-02	7.343E-02	1.154E-02	1.426E-01	8.558E-03	8.689E-02
RATIO=	2.917	3.206E+00	3.149E+00	3.347E+00	3.417E+00	3.402E+00	3.590E+00	3.555E+00	3.598E+00
MEAN =	3.857								
RMS =	0.108	2.534E-02	2.328E-02	8.544E-03	5.426E-02	9.337E-03	1.095E-01	6.334E-03	6.833E-02
MAX =	0.338	9.027E-02	6.212E-02	3.078E-02	1.686E-01	3.214E-02	4.191E-01	2.490E-02	2.402E-01
RATIO=	3.129	3.562E+00	2.668E+00	3.602E+00	3.108E+00	3.443E+00	3.829E+00	3.931E+00	3.515E+00
MEAN =	4.563								
RMS =	0.134	3.271E-02	2.957E-02	1.130E-02	7.350E-02	1.253E-02	1.469E-01	8.365E-03	9.294E-02
MAX =	0.367	9.040E-02	8.461E-02	4.510E-02	2.382E-01	4.180E-02	5.542E-01	2.741E-02	3.068E-01
RATIO=	2.739	2.763E+00	2.861E+00	3.990E+00	3.241E+00	3.336E+00	3.772E+00	3.277E+00	3.301E+00
MEAN =	6.140								
RMS =	0.145	9.468E-02	6.676E-02	2.900E-02	1.660E-01	3.307E-02	3.868E-01	2.265E-02	2.360E-01
MAX =	0.440	2.569E-01	2.338E-01	8.123E-02	5.313E-01	9.289E-02	1.016E+00	6.583E-02	7.517E-01
RATIO=	3.028	2.714E+00	3.502E+00	2.801E+00	3.200E+00	2.809E+00	2.627E+00	2.907E+00	3.186E+00
MEAN =	7.580								
RMS =	0.093	1.018E-01	1.112E-01	3.464E-02	2.291E-01	4.048E-02	4.738E-01	2.680E-02	3.003E-01
MAX =	0.306	2.897E-01	2.816E-01	1.211E-01	6.858E-01	1.546E-01	1.933E+00	1.048E-01	1.066E+00
RATIO=	3.290	2.847E+00	2.533E+00	3.495E+00	2.993E+00	3.819E+00	4.080E+00	3.912E+00	3.548E+00

ONE BOX WITH FAIRINGS IN HIGH TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S. CENTER BND(CM)	TOR(DEG.)	N. CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	2.176								
RMS =	0.150	5.535E-03	5.389E-03	2.035E-03	1.898E-02	2.465E-03	2.865E-02	1.714E-03	2.025E-02
MAX =	0.423	1.398E-02	1.540E-02	7.049E-03	5.337E-02	7.938E-03	7.741E-02	5.213E-03	6.691E-02
RATIO=	2.823	2.526E+00	2.858E+00	3.465E+00	2.811E+00	3.220E+00	2.702E+00	3.042E+00	3.305E+00
MEAN =	2.247								
RMS =	0.095	6.681E-03	6.000E-03	2.190E-03	1.892E-02	2.514E-03	2.939E-02	1.740E-03	1.925E-02
MAX =	0.249	1.847E-02	1.691E-02	7.491E-03	5.293E-02	7.200E-03	9.009E-02	6.380E-03	6.796E-02
RATIO=	2.609	2.764E+00	2.818E+00	3.420E+00	2.798E+00	2.863E+00	3.065E+00	3.666E+00	3.530E+00
MEAN =	2.561								
RMS =	0.092	8.339E-03	9.739E-03	2.746E-03	2.259E-02	2.916E-03	3.416E-02	2.127E-03	2.554E-02
MAX =	0.316	2.664E-02	3.219E-02	7.005E-03	6.673E-02	9.915E-03	1.314E-01	7.764E-03	9.448E-02
RATIO=	3.420	3.195E+00	3.305E+00	2.551E+00	2.953E+00	3.400E+00	3.847E+00	3.651E+00	3.699E+00
MEAN =	2.633								
RMS =	0.089	7.879E-03	1.186E-02	2.479E-03	2.247E-02	3.008E-03	3.505E-02	2.055E-03	2.291E-02
MAX =	0.294	2.509E-02	3.870E-02	7.806E-03	8.367E-02	8.791E-03	1.495E-01	5.482E-03	7.846E-02
RATIO=	3.322	3.184E+00	3.262E+00	3.149E+00	3.724E+00	2.922E+00	4.264E+00	3.154E+00	3.424E+00
MEAN =	2.886								
RMS =	0.091	1.245E-02	1.509E-02	4.435E-03	3.094E-02	4.773E-03	5.569E-02	3.302E-03	3.988E-02
MAX =	0.245	3.623E-02	5.803E-02	1.309E-02	8.571E-02	1.336E-02	1.666E-01	8.042E-03	1.042E-01
RATIO=	2.701	2.909E+00	3.847E+00	2.951E+00	2.770E+00	2.799E+00	2.992E+00	2.435E+00	2.612E+00
MEAN =	3.704								
RMS =	0.085	2.261E-02	2.457E-02	7.504E-03	4.907E-02	8.813E-03	1.028E-01	6.033E-03	6.601E-02
MAX =	0.282	4.669E-02	7.579E-02	2.245E-02	1.546E-01	2.161E-02	3.044E-01	1.663E-02	1.975E-01
RATIO=	3.324	2.065E+00	3.084E+00	2.992E+00	3.151E+00	2.452E+00	2.960E+00	2.756E+00	2.992E+00
MEAN =	4.765								
RMS =	0.155	4.128E-02	3.399E-02	1.261E-02	7.654E-02	1.436E-02	1.673E-01	1.001E-02	1.034E-01
MAX =	0.400	1.224E-01	1.177E-01	4.035E-02	3.285E-01	4.129E-02	5.309E-01	2.734E-02	3.407E-01
RATIO=	2.584	2.964E+00	3.461E+00	3.201E+00	4.292E+00	2.875E+00	3.173E+00	2.730E+00	3.295E+00
MEAN =	6.241								
RMS =	0.095	6.171E-02	6.853E-02	2.160E-02	1.419E-01	2.506E-02	2.920E-01	1.668E-02	1.894E-01
MAX =	0.266	1.945E-01	1.921E-01	6.840E-02	4.710E-01	9.324E-02	1.079E+00	5.125E-02	6.313E-01
RATIO=	2.804	3.152E+00	2.802E+00	3.167E+00	3.319E+00	3.721E+00	3.696E+00	3.072E+00	3.333E+00
MEAN =	7.437								
RMS =	0.116	1.074E-01	1.215E-01	3.827E-02	2.504E-01	4.542E-02	5.276E-01	3.056E-02	3.577E-01
MAX =	0.280	2.831E-01	3.567E-01	1.116E-01	8.259E-01	1.495E-01	1.692E+00	1.058E-01	1.132E+00
RATIO=	2.413	2.636E+00	2.936E+00	2.916E+00	3.298E+00	3.292E+00	3.208E+00	3.462E+00	3.166E+00

TWO BOXES IN SMOOTH FLOW

	WIND SPEED	CENTER		S.CENTER		N.CENTER		SIDE SPAN	
	(M/SEC)	BND(CM)	TOR(DEG.)	BND(CM)	TOR(DEG.)	BND(CM)	TOR(DEG.)	BND(CM)	TOR(DEG.)
MEAN =	4.531								
RMS =	0.076	3.649E-02	1.573E-02	2.584E-02	3.750E-01	3.770E-02	4.503E-01	3.675E-03	1.337E-01
MAX =	0.234	7.346E-02	4.485E-02	4.128E-02	5.934E-01	6.410E-02	7.508E-01	9.186E-03	2.472E-01
RATIO=	3.085	2.013E+00	2.851E+00	1.597E+00	1.583E+00	1.700E+00	1.667E+00	2.500E+00	1.849E+00
MEAN =	3.882								
RMS =	0.099	4.706E-03	1.471E-02	1.165E-02	1.446E-01	2.025E-02	2.409E-01	1.591E-02	4.657E-01
MAX =	0.341	1.586E-02	3.702E-02	2.045E-02	2.530E-01	3.162E-02	4.124E-01	2.466E-02	6.939E-01
RATIO=	3.437	3.370E+00	2.517E+00	1.756E+00	1.750E+00	1.562E+00	1.712E+00	1.550E+00	1.490E+00
MEAN =	3.778								
RMS =	0.074	5.831E-03	1.618E-02	1.249E-02	1.532E-01	2.125E-02	2.516E-01	1.742E-02	5.059E-01
MAX =	0.203	1.769E-02	4.728E-02	2.179E-02	2.613E-01	3.523E-02	4.327E-01	2.879E-02	7.985E-01
RATIO=	2.728	3.035E+00	2.923E+00	1.744E+00	1.706E+00	1.658E+00	1.720E+00	1.653E+00	1.578E+00
MEAN =	3.839								
RMS =	0.075	5.635E-03	1.783E-02	1.244E-02	1.533E-01	2.172E-02	2.593E-01	1.762E-02	5.133E-01
MAX =	0.225	1.742E-02	5.024E-02	2.200E-02	2.599E-01	3.644E-02	4.435E-01	2.847E-02	7.732E-01
RATIO=	2.979	3.091E+00	2.819E+00	1.768E+00	1.695E+00	1.677E+00	1.710E+00	1.616E+00	1.506E+00
MEAN =	4.536								
RMS =	0.077	2.402E-02	1.045E-02	1.704E-02	2.492E-01	2.477E-02	2.962E-01	2.820E-03	9.269E-02
MAX =	0.222	5.610E-02	3.231E-02	3.417E-02	5.038E-01	4.510E-02	5.497E-01	7.782E-03	1.843E-01
RATIO=	2.893	2.336E+00	3.092E+00	2.006E+00	2.022E+00	1.821E+00	1.856E+00	2.760E+00	1.988E+00
MEAN =	13.773								
RMS =	0.078	2.800E-02	1.982E-01	1.188E-02	1.399E-01	1.580E-02	1.960E-01	8.562E-03	1.397E-01
MAX =	0.508	8.284E-02	4.131E-01	3.215E-02	4.515E-01	4.974E-02	6.330E-01	2.301E-02	4.167E-01
RATIO=	6.483	2.958E+00	2.084E+00	2.705E+00	3.227E+00	3.147E+00	3.229E+00	2.687E+00	2.983E+00
MEAN =	14.920								
RMS =	0.087	3.751E-02	3.798E-01	1.403E-02	1.659E-01	1.802E-02	2.410E-01	9.929E-03	1.544E-01
MAX =	0.366	1.372E-01	9.201E-01	3.829E-02	5.289E-01	5.755E-02	7.453E-01	2.801E-02	4.925E-01
RATIO=	4.217	3.658E+00	2.423E+00	2.730E+00	3.188E+00	3.194E+00	3.093E+00	2.821E+00	3.189E+00
MEAN =	15.609								
RMS =	0.086	5.918E-02	2.088E+00	1.689E-02	5.561E-01	3.202E-02	7.473E-01	1.275E-02	2.779E-01
MAX =	0.468	1.774E-01	3.484E+00	4.693E-02	1.229E+00	1.017E-01	1.533E+00	4.044E-02	8.174E-01
RATIO=	5.445	2.998E+00	1.669E+00	2.779E+00	2.211E+00	3.176E+00	2.052E+00	3.171E+00	2.941E+00
MEAN =	15.265								
RMS =	0.087	3.900E-02	6.313E-01	1.447E-02	2.241E-01	1.869E-02	2.757E-01	9.951E-03	1.801E-01
MAX =	0.402	1.222E-01	1.334E+00	5.178E-02	7.683E-01	5.415E-02	7.153E-01	3.120E-02	5.270E-01
RATIO=	4.616	3.134E+00	2.113E+00	3.577E+00	3.428E+00	2.897E+00	2.594E+00	3.135E+00	2.926E+00

TWO BOXES IN LOW TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	8.001								
RMS =	0.080	4.378E-02	6.735E-02	1.620E-02	2.507E-02	1.875E-02	2.215E-01	1.194E-02	1.514E-01
MAX =	0.347	1.371E-01	1.775E-01	5.538E-02	6.606E-02	6.133E-02	7.282E-01	3.386E-02	4.910E-01
RATIO=	4.356	3.131E+00	2.635E+00	3.418E+00	2.635E+00	3.270E+00	3.288E+00	2.837E+00	3.244E+00
MEAN =	9.632								
RMS =	0.080	6.710E-02	1.106E-01	2.418E-02	3.778E-02	2.631E-02	3.114E-01	1.667E-02	2.185E-01
MAX =	0.388	2.075E-01	3.280E-01	8.151E-02	1.194E-01	8.377E-02	9.002E-01	5.906E-02	6.553E-01
RATIO=	4.821	3.092E+00	2.967E+00	3.371E+00	3.160E+00	3.184E+00	2.891E+00	3.543E+00	3.000E+00
MEAN =	10.596								
RMS =	0.080	7.092E-02	1.288E-01	2.788E-02	4.443E-02	3.243E-02	3.835E-01	2.054E-02	2.822E-01
MAX =	0.420	2.278E-01	4.244E-01	7.586E-02	1.289E-01	1.265E-01	9.729E-01	6.565E-02	1.013E+00
RATIO=	5.244	3.212E+00	3.295E+00	2.721E+00	2.901E+00	3.902E+00	2.537E+00	3.196E+00	3.588E+00
MEAN =	11.559								
RMS =	0.084	9.380E-02	2.166E-01	3.980E-02	5.419E-02	4.620E-02	5.468E-01	2.933E-02	3.892E-01
MAX =	0.327	2.767E-01	6.477E-01	1.083E-01	1.372E-01	1.334E-01	1.920E+00	9.729E-02	1.415E+00
RATIO=	3.896	2.950E+00	2.991E+00	2.720E+00	3.072E+00	2.888E+00	3.512E+00	3.317E+00	3.635E+00
MEAN =	12.522								
RMS =	0.084	7.813E-02	2.279E-01	3.666E-02	6.876E-02	4.529E-02	5.372E-01	2.718E-02	3.809E-01
MAX =	0.332	2.583E-01	5.491E-01	1.100E-01	2.244E-01	1.318E-01	1.518E+00	7.321E-02	1.243E+00
RATIO=	3.963	3.306E+00	2.409E+00	3.001E+00	3.264E+00	2.911E+00	2.826E+00	2.693E+00	3.264E+00
MEAN =	13.485								
RMS =	0.087	1.098E-01	3.238E-01	4.011E-02	9.280E-02	4.895E-02	5.843E-01	3.003E-02	3.991E-01
MAX =	0.502	3.461E-01	8.258E-01	1.149E-01	2.467E-01	1.487E-01	2.004E+00	9.227E-02	1.247E+00
RATIO=	5.749	3.151E+00	2.551E+00	2.865E+00	2.658E+00	3.037E+00	3.430E+00	3.072E+00	3.124E+00
MEAN =	14.448								
RMS =	0.097	1.180E-01	4.546E-01	4.616E-02	1.290E-01	5.590E-02	6.768E-01	3.424E-02	4.665E-01
MAX =	0.442	3.912E-01	1.680E+00	1.553E-01	4.734E-01	2.027E-01	1.946E+00	9.924E-02	1.627E+00
RATIO=	4.552	3.315E+00	3.697E+00	3.364E+00	3.669E+00	3.626E+00	2.876E+00	2.899E+00	3.488E+00
MEAN =	15.412								
RMS =	0.090	1.189E-01	1.288E+00	4.923E-02	3.403E-01	6.234E-02	8.487E-01	3.574E-02	4.869E-01
MAX =	0.471	4.188E-01	2.907E+00	1.632E-01	8.177E-01	1.836E-01	2.918E+00	1.311E-01	1.409E+00
RATIO=	5.213	3.523E+00	2.257E+00	3.315E+00	2.403E+00	2.944E+00	3.438E+00	3.667E+00	2.893E+00
MEAN =	15.797								
RMS =	0.087	1.326E-01	1.068E+00	5.254E-02	2.849E-01	6.646E-02	8.722E-01	3.872E-02	5.289E-01
MAX =	0.617	3.864E-01	2.607E+00	1.669E-01	8.170E-01	1.958E-01	2.610E+00	1.178E-01	1.802E+00
RATIO=	7.054	2.914E+00	2.442E+00	3.177E+00	2.868E+00	2.946E+00	2.992E+00	3.043E+00	3.407E+00
MEAN =	3.200								
RMS =	0.089	4.852E-03	9.202E-03	4.574E-03	1.250E-02	7.052E-03	8.341E-02	5.091E-03	1.680E-01
MAX =	0.281	1.337E-02	2.556E-02	1.006E-02	2.485E-02	1.429E-02	1.674E-01	9.570E-03	2.790E-01
RATIO=	3.151	2.755E+00	2.778E+00	2.198E+00	1.988E+00	2.026E+00	2.006E+00	1.880E+00	1.661E+00

TWO BOXES IN HIGH TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	2.728								
RMS =	0.120	1.058E-02	1.246E-02	3.738E-03	2.734E-02	4.168E-03	4.907E-02	2.832E-03	3.353E-02
MAX =	0.314	3.306E-02	2.924E-02	9.729E-03	8.236E-02	1.221E-02	1.483E-01	8.279E-03	1.022E-01
RATIO=	2.607	3.124E+00	2.347E+00	2.603E+00	3.012E+00	2.928E+00	3.023E+00	2.923E+00	3.049E+00
MEAN =	3.131								
RMS =	0.100	9.413E-03	1.315E-02	3.024E-03	2.484E-02	3.349E-03	3.957E-02	2.285E-03	2.918E-02
MAX =	0.263	3.301E-02	3.375E-02	9.972E-03	7.001E-02	9.593E-03	1.396E-01	6.605E-03	9.871E-02
RATIO=	2.633	3.507E+00	2.567E+00	3.298E+00	2.818E+00	2.865E+00	3.528E+00	2.890E+00	3.383E+00
MEAN =	2.805								
RMS =	0.085	9.816E-03	9.161E-03	3.246E-03	2.484E-02	3.985E-03	4.685E-02	2.690E-03	3.318E-02
MAX =	0.244	2.793E-02	2.421E-02	9.472E-03	8.027E-02	1.027E-02	1.458E-01	8.045E-03	9.664E-02
RATIO=	2.891	2.845E+00	2.643E+00	2.918E+00	3.232E+00	2.578E+00	3.113E+00	2.990E+00	2.912E+00
MEAN =	3.750								
RMS =	0.127	2.331E-02	3.481E-02	8.284E-03	6.210E-02	9.771E-03	1.150E-01	6.117E-03	7.183E-02
MAX =	0.297	6.378E-02	8.764E-02	2.421E-02	1.825E-01	3.147E-02	3.629E-01	1.795E-02	2.199E-01
RATIO=	2.348	2.736E+00	2.517E+00	2.923E+00	2.940E+00	3.220E+00	3.156E+00	2.934E+00	3.061E+00
MEAN =	4.718								
RMS =	0.119	2.911E-02	2.968E-02	1.004E-02	7.686E-02	1.211E-02	1.420E-01	7.872E-03	9.217E-02
MAX =	0.296	9.317E-02	7.544E-02	3.060E-02	2.203E-01	4.828E-02	4.362E-01	2.471E-02	2.721E-01
RATIO=	2.493	3.201E+00	2.542E+00	3.047E+00	2.866E+00	3.988E+00	3.073E+00	3.139E+00	2.952E+00
MEAN =	5.384								
RMS =	0.080	6.060E-02	5.405E-02	1.846E-02	1.131E-01	2.103E-02	2.463E-01	1.439E-02	1.531E-01
MAX =	0.234	1.723E-01	1.707E-01	5.540E-02	3.200E-01	7.213E-02	6.648E-01	3.873E-02	4.137E-01
RATIO=	2.910	2.843E+00	3.159E+00	3.001E+00	2.830E+00	3.430E+00	2.699E+00	2.692E+00	2.703E+00
MEAN =	6.745								
RMS =	0.134	8.691E-02	8.377E-02	2.951E-02	1.944E-01	3.358E-02	3.940E-01	2.247E-02	2.572E-01
MAX =	0.338	2.376E-01	2.607E-01	8.377E-02	7.180E-01	1.231E-01	1.137E+00	6.080E-02	8.190E-01
RATIO=	2.524	2.734E+00	3.112E+00	2.838E+00	3.693E+00	3.664E+00	2.887E+00	2.705E+00	3.184E+00
MEAN =	7.901								
RMS =	0.087	1.358E-01	9.732E-02	4.519E-02	2.708E-01	5.199E-02	6.074E-01	3.547E-02	3.919E-01
MAX =	0.252	4.294E-01	3.426E-01	1.587E-01	9.032E-01	1.757E-01	1.990E+00	1.064E-01	1.322E+00
RATIO=	2.889	3.161E+00	3.520E+00	3.513E+00	3.335E+00	3.380E+00	3.276E+00	2.999E+00	3.373E+00

TWO BOXES WITH FAIRINGS IN LOW TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	CENTER TOR(DEG.)	S.CENTER BND(CM)	S.CENTER TOR(DEG.)	N.CENTER BND(CM)	N.CENTER TOR(DEG.)	SIDE SPAN BND(CM)	SIDE SPAN TOR(DEG.)
MEAN =	4.259								
RMS =	0.092	9.822E-03	2.663E-02	5.673E-03	1.351E-02	6.408E-03	7.600E-02	2.274E-03	3.613E-02
MAX =	0.301	3.208E-02	7.790E-02	1.628E-02	3.668E-02	2.019E-02	2.057E-01	5.938E-03	1.113E-01
RATIO=	3.270	3.266E+00	2.925E+00	2.869E+00	2.715E+00	3.151E+00	2.706E+00	2.611E+00	3.081E+00
MEAN =	5.253								
RMS =	0.078	1.712E-02	2.839E-02	7.673E-03	1.657E-02	8.186E-03	9.764E-02	4.506E-03	8.090E-02
MAX =	0.233	4.786E-02	6.845E-02	2.866E-02	4.545E-02	2.355E-02	3.322E-01	1.478E-02	2.024E-01
RATIO=	2.972	2.796E+00	2.411E+00	3.736E+00	2.743E+00	2.877E+00	3.402E+00	3.280E+00	2.502E+00
MEAN =	6.259								
RMS =	0.082	2.322E-02	2.813E-02	8.260E-03	1.655E-02	9.530E-03	1.122E-01	5.884E-03	7.152E-02
MAX =	0.271	7.473E-02	7.561E-02	2.773E-02	4.526E-02	2.863E-02	3.615E-01	1.760E-02	2.301E-01
RATIO=	3.301	3.218E+00	2.688E+00	3.357E+00	2.735E+00	3.004E+00	3.222E+00	2.992E+00	3.217E+00
MEAN =	7.100								
RMS =	0.086	3.294E-02	4.444E-02	1.264E-02	2.103E-02	1.404E-02	1.655E-01	8.954E-03	1.096E-01
MAX =	0.376	1.047E-01	1.372E-01	5.261E-02	6.836E-02	5.116E-02	5.271E-01	3.167E-02	3.475E-01
RATIO=	4.382	3.179E+00	3.088E+00	4.163E+00	3.251E+00	3.645E+00	3.183E+00	3.537E+00	3.170E+00
MEAN =	8.230								
RMS =	0.084	5.115E-02	6.001E-02	1.877E-02	2.608E-02	2.070E-02	2.442E-01	1.339E-02	1.649E-01
MAX =	0.382	1.817E-01	1.705E-01	5.356E-02	6.841E-02	6.933E-02	7.141E-01	4.329E-02	5.383E-01
RATIO=	4.568	3.553E+00	2.841E+00	2.854E+00	2.623E+00	3.350E+00	2.924E+00	3.232E+00	3.265E+00
MEAN =	8.669								
RMS =	0.083	4.837E-02	8.326E-02	1.889E-02	3.368E-02	2.048E-02	2.432E-01	1.296E-02	1.760E-01
MAX =	0.373	1.717E-01	2.575E-01	6.634E-02	8.874E-02	6.360E-02	1.004E+00	5.036E-02	5.963E-01
RATIO=	4.475	3.550E+00	3.093E+00	3.512E+00	2.635E+00	3.105E+00	4.126E+00	3.886E+00	3.389E+00
MEAN =	9.632								
RMS =	0.078	8.655E-02	1.136E-01	3.053E-02	3.994E-02	3.415E-02	4.030E-01	2.270E-02	2.705E-01
MAX =	0.230	2.474E-01	3.634E-01	9.342E-02	1.442E-01	1.114E-01	1.216E+00	6.835E-02	7.955E-01
RATIO=	2.952	2.859E+00	3.199E+00	3.060E+00	3.610E+00	3.263E+00	3.016E+00	3.011E+00	2.941E+00
MEAN =	10.596								
RMS =	0.085	8.990E-02	1.262E-01	3.228E-02	4.723E-02	3.607E-02	4.272E-01	2.299E-02	2.798E-01
MAX =	0.380	2.807E-01	3.161E-01	1.046E-01	1.304E-01	1.112E-01	1.322E+00	6.410E-02	7.432E-01
RATIO=	4.488	3.123E+00	2.505E+00	3.241E+00	2.761E+00	3.082E+00	3.094E+00	2.788E+00	2.656E+00
MEAN =	11.559								
RMS =	0.089	9.223E-02	1.383E-01	3.566E-02	5.284E-02	4.012E-02	4.746E-01	2.565E-02	3.231E-01
MAX =	0.364	2.513E-01	4.113E-01	1.042E-01	1.606E-01	1.215E-01	1.593E+00	7.248E-02	1.019E+00
RATIO=	4.110	2.725E+00	2.975E+00	2.922E+00	3.040E+00	3.029E+00	3.356E+00	2.826E+00	3.154E+00
MEAN =	12.522								
RMS =	0.092	9.030E-02	2.259E-01	3.728E-02	7.628E-02	4.173E-02	4.983E-01	2.595E-02	3.571E-01
MAX =	0.434	3.046E-01	5.461E-01	1.273E-01	2.257E-01	1.308E-01	1.998E+00	9.629E-02	1.344E+00
RATIO=	4.723	3.373E+00	2.418E+00	3.414E+00	2.959E+00	3.133E+00	4.010E+00	3.711E+00	3.764E+00

TWO BOXES WITH FAIRINGS IN LOW TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	13.485								
RMS =	0.090	1.209E-01	2.892E-01	4.947E-02	9.465E-02	5.441E-02	6.520E-01	3.394E-02	4.504E-01
MAX =	0.447	3.612E-01	8.955E-01	1.561E-01	3.635E-01	1.846E-01	1.952E+00	1.007E-01	1.461E+00
RATIO=	4.959	2.987E+00	3.096E+00	3.154E+00	3.840E+00	3.393E+00	2.994E+00	2.966E+00	3.243E+00
MEAN =	14.448								
RMS =	0.094	1.329E-01	4.608E-01	5.419E-02	1.405E-01	5.909E-02	7.164E-01	3.562E-02	4.776E-01
MAX =	0.655	4.493E-01	1.232E+00	1.552E-01	3.844E-01	1.803E-01	2.275E+00	1.166E-01	1.705E+00
RATIO=	6.938	3.380E+00	2.674E+00	2.864E+00	2.737E+00	3.052E+00	3.175E+00	3.274E+00	3.570E+00
MEAN =	15.412								
RMS =	0.131	1.241E-01	8.025E-01	5.895E-02	2.383E-01	6.661E-02	8.422E-01	3.980E-02	5.851E-01
MAX =	1.087	3.565E-01	2.098E+00	2.041E-01	6.304E-01	2.109E-01	2.368E+00	1.363E-01	1.624E+00
RATIO=	8.328	2.874E+00	2.614E+00	3.462E+00	2.646E+00	3.166E+00	2.811E+00	3.426E+00	2.776E+00

TWO BOXES WITH FAIRINGS IN HIGH TURBULENT FLOW

	WIND SPEED (M/SEC)	CENTER BND(CM)	TOR(DEG.)	S.CENTER BND(CM)	TOR(DEG.)	N.CENTER BND(CM)	TOR(DEG.)	SIDE SPAN BND(CM)	TOR(DEG.)
MEAN =	2.895								
RMS =	0.176	1.208E-02	8.771E-03	3.540E-03	2.442E-02	4.094E-03	5.040E-02	2.654E-03	2.813E-02
MAX =	0.443	2.995E-02	2.304E-02	8.898E-03	7.600E-02	1.248E-02	1.502E-01	7.260E-03	8.051E-02
RATIO=	2.523	2.480E+00	2.627E+00	2.514E+00	3.112E+00	3.048E+00	2.981E+00	2.735E+00	2.862E+00
MEAN =	4.367								
RMS =	0.179	2.354E-02	3.550E-02	7.096E-03	4.702E-02	8.424E-03	1.034E-01	5.211E-03	5.606E-02
MAX =	0.354	5.869E-02	9.719E-02	2.187E-02	1.475E-01	2.344E-02	3.340E-01	1.500E-02	1.899E-01
RATIO=	1.979	2.493E+00	2.738E+00	3.082E+00	3.137E+00	2.782E+00	3.230E+00	2.878E+00	3.387E+00
MEAN =	5.196								
RMS =	0.118	2.800E-02	3.349E-02	1.021E-02	7.182E-02	1.213E-02	1.498E-01	7.370E-03	8.657E-02
MAX =	0.407	7.516E-02	9.053E-02	3.115E-02	2.074E-01	3.507E-02	4.390E-01	2.142E-02	2.731E-01
RATIO=	3.451	2.684E+00	2.703E+00	3.050E+00	2.887E+00	2.892E+00	2.951E+00	2.907E+00	3.154E+00
MEAN =	5.835								
RMS =	0.110	4.045E-02	5.836E-02	1.553E-02	1.098E-01	1.979E-02	2.418E-01	1.192E-02	1.458E-01
MAX =	0.279	1.515E-01	1.667E-01	5.214E-02	3.253E-01	6.621E-02	8.655E-01	4.011E-02	4.256E-01
RATIO=	2.526	3.745E+00	2.857E+00	3.356E+00	2.972E+00	3.345E+00	3.580E+00	3.366E+00	2.919E+00
MEAN =	6.599								
RMS =	0.146	7.271E-02	6.928E-02	2.421E-02	1.554E-01	2.925E-02	3.590E-01	1.817E-02	2.024E-01
MAX =	0.379	1.933E-01	2.166E-01	7.961E-02	4.924E-01	9.165E-02	1.118E+00	5.679E-02	7.420E-01
RATIO=	2.591	2.658E+00	3.126E+00	3.289E+00	3.168E+00	3.133E+00	3.116E+00	3.126E+00	3.666E+00
MEAN =	7.901								
RMS =	0.114	9.962E-02	9.573E-02	3.650E-02	2.471E-01	4.527E-02	5.556E-01	2.789E-02	3.270E-01
MAX =	0.339	3.009E-01	3.345E-01	1.143E-01	7.496E-01	1.776E-01	1.887E+00	8.888E-02	1.044E+00
RATIO=	2.981	3.020E+00	3.494E+00	3.133E+00	3.034E+00	3.923E+00	3.396E+00	3.186E+00	3.193E+00

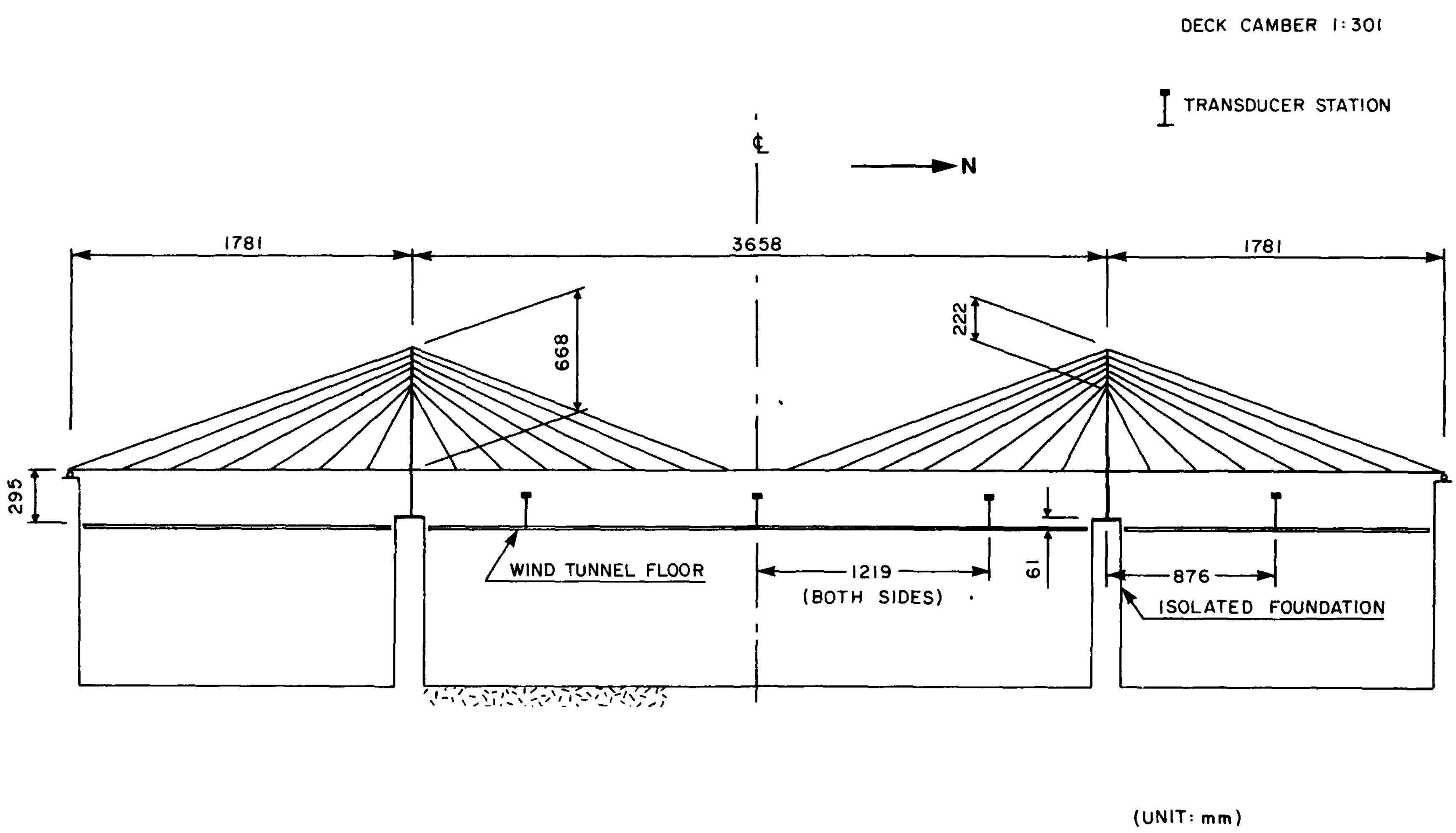


FIG. 1: ELEVATION OF MODEL

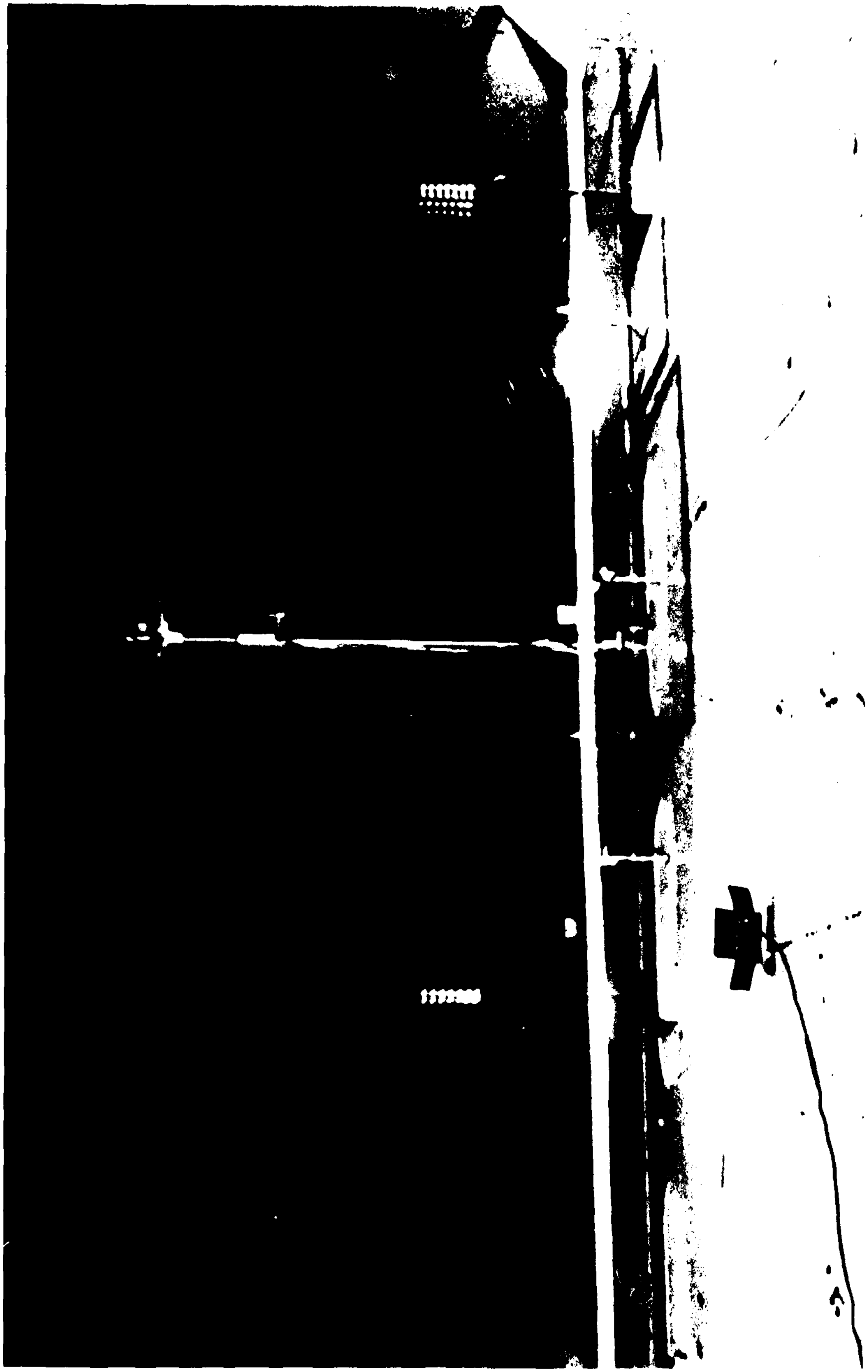


FIG. 2: MODEL INSTALLATION

CABLE NO.	EA(10^3N)	CABLE TENSION (N)	CABLE NO.	EA(10^3N)	CABLE TENSION (N)
1	12.9	7.93	8	5.2	3.81
2	12.9	9.73	9	5.2	4.63
3	10.6	7.77	10	5.2	5.52
4	10.6	6.91	11	8.6	6.78
5	5.2	5.80	12	8.6	8.22
6	5.2	4.75	13	8.6	8.74
7	5.2	3.88	14	10.6	9.12

(UNIT: mm)

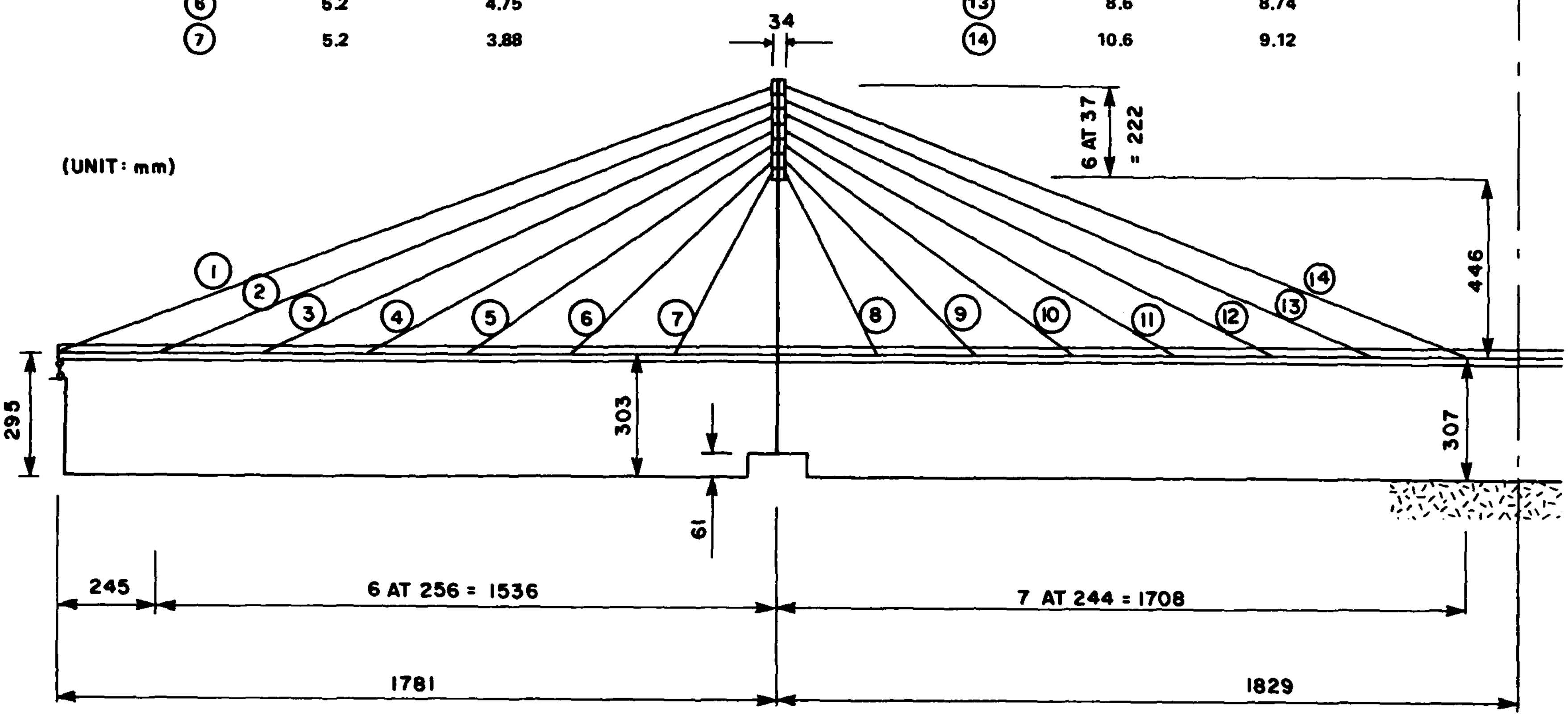


FIG. 3: CABLE ARRANGEMENT

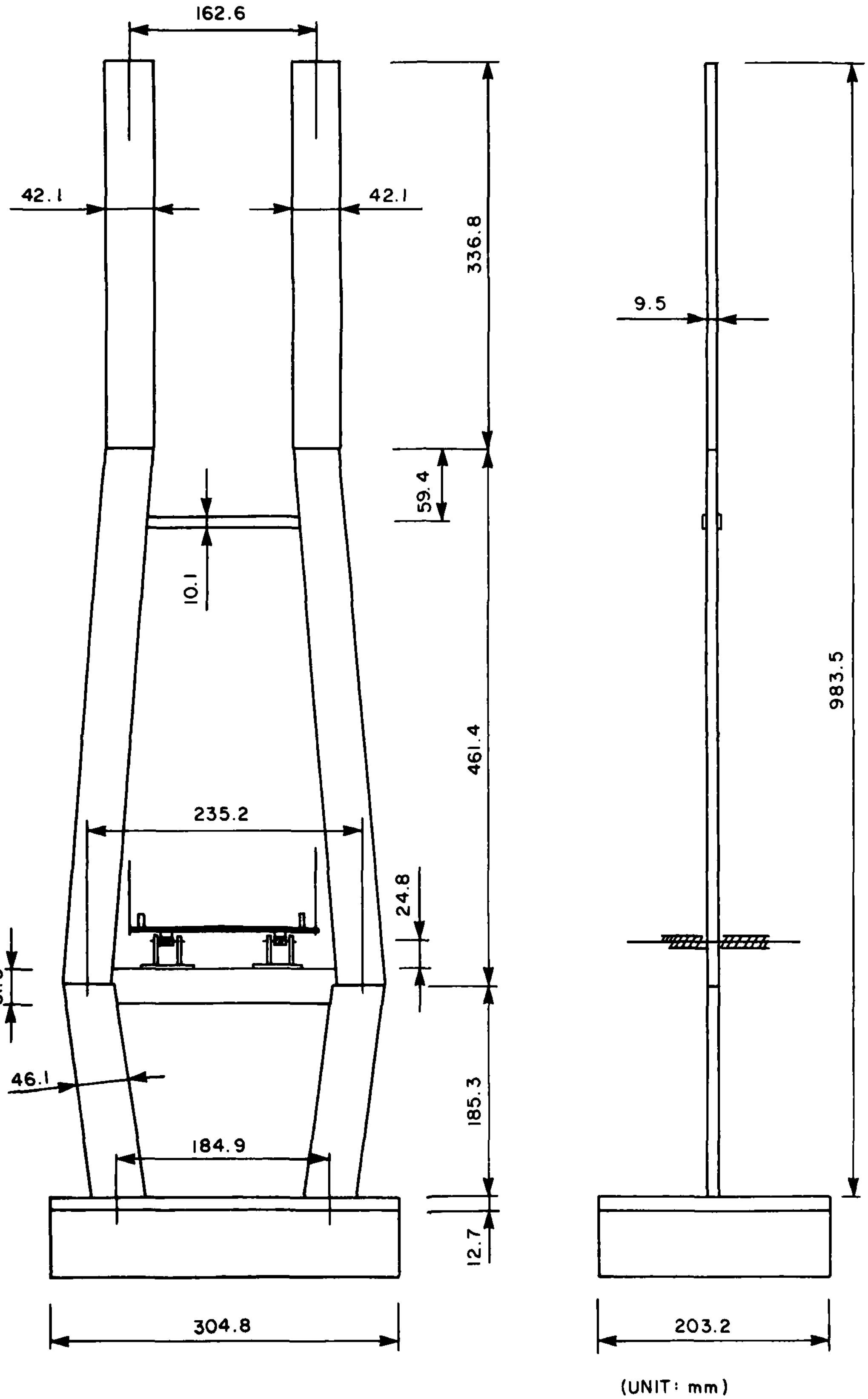


FIG. 4: TOWER (STEEL)

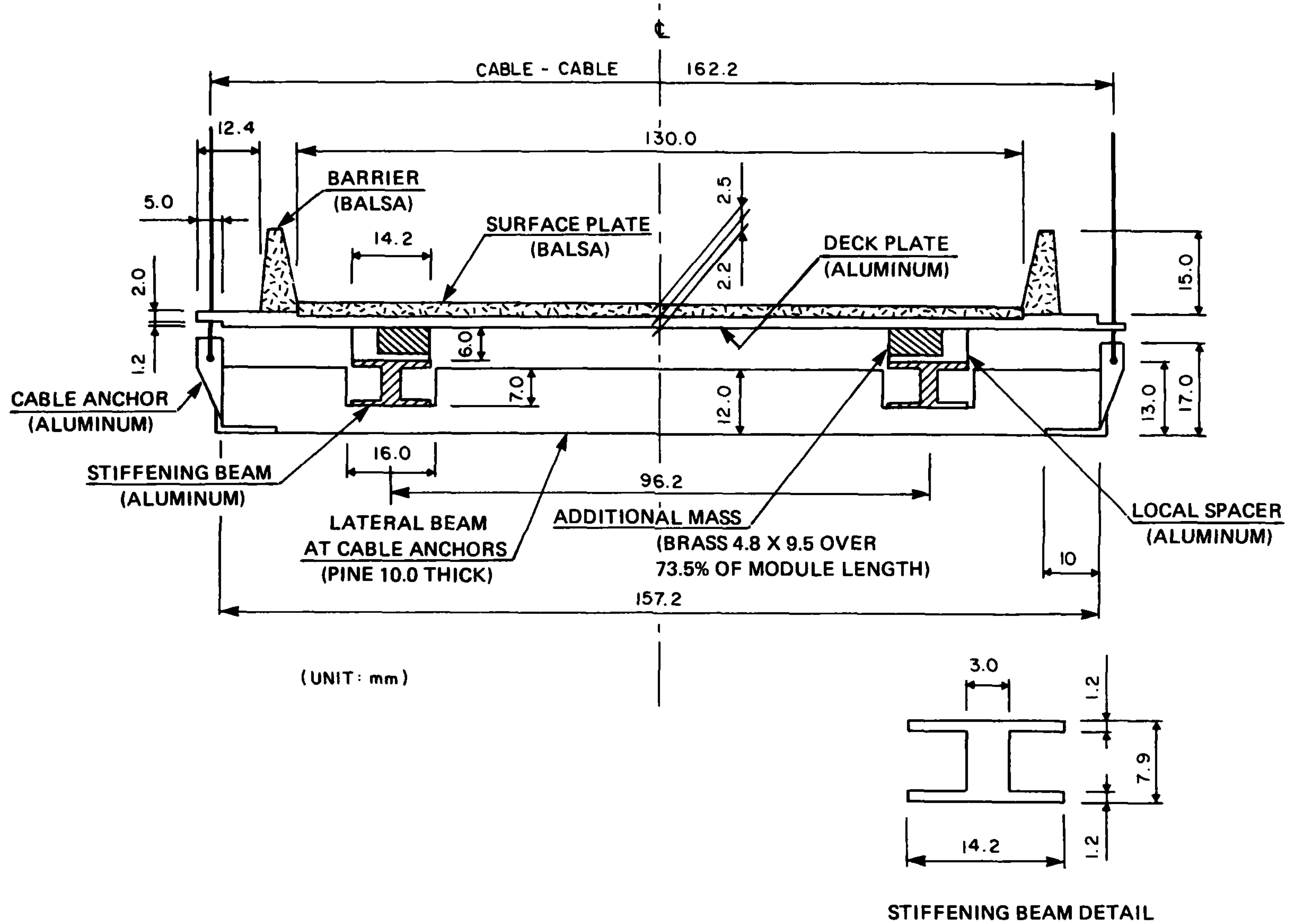


FIG. 5: BRIDGE DECK AND FLOOR SYSTEM WITH CABLES

COMMON ELEMENT FOR EACH CONFIGURATION

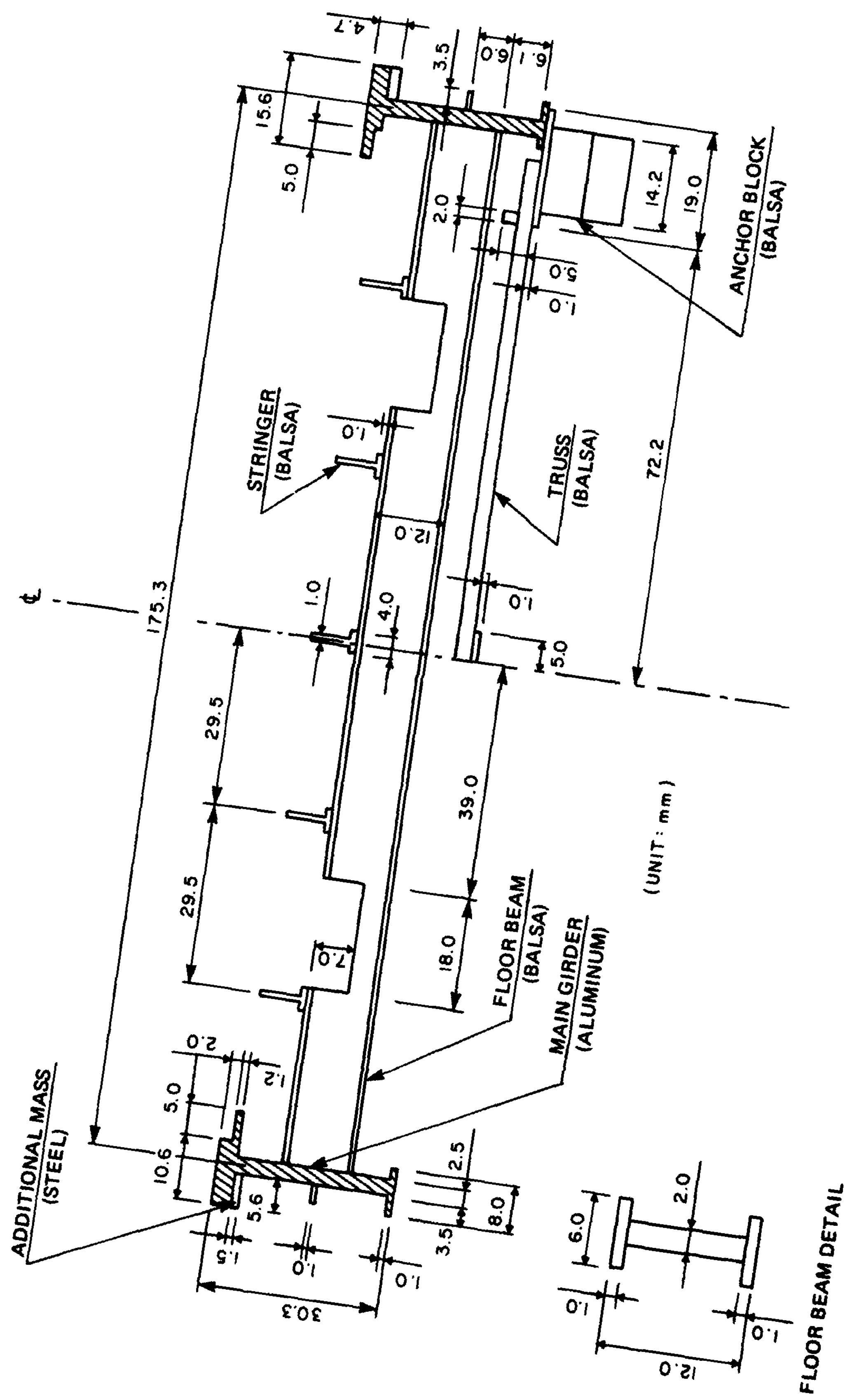
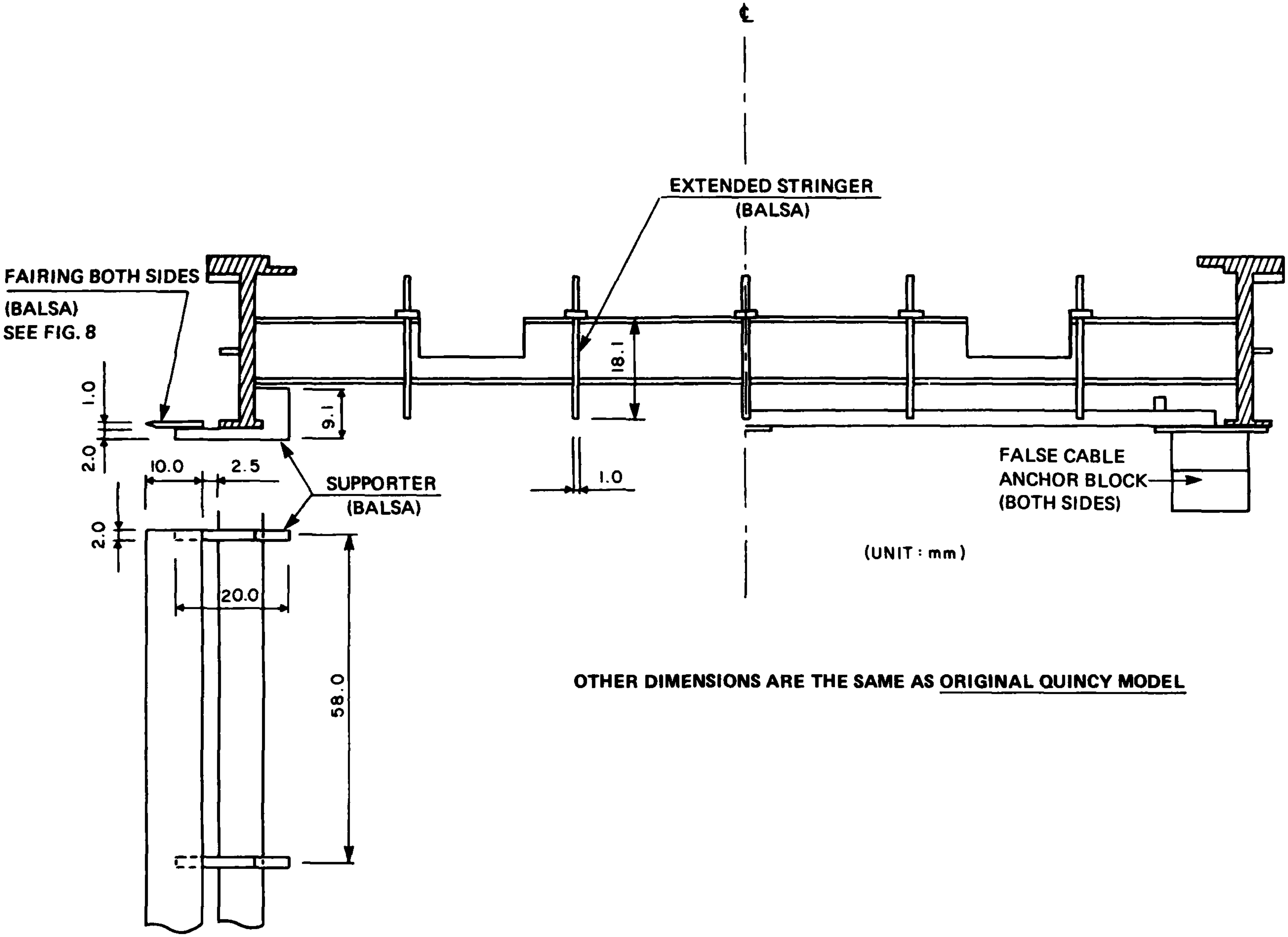


FIG. 6: INSERT FOR ORIGINAL QUINCY MODEL



OTHER DIMENSIONS ARE THE SAME AS ORIGINAL QUINCY MODEL

FIG. 7: INSERT FOR FINAL QUINCY MODEL

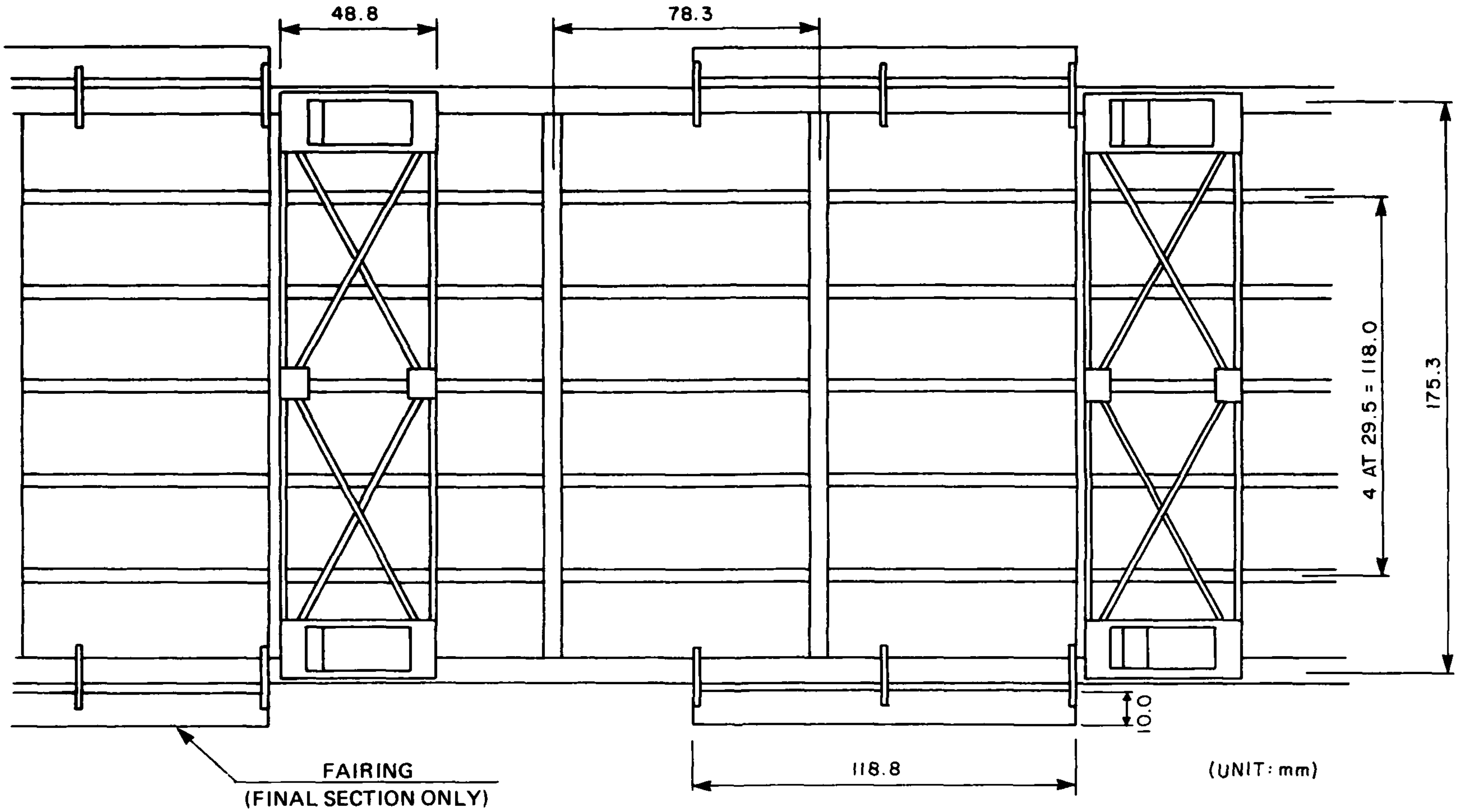
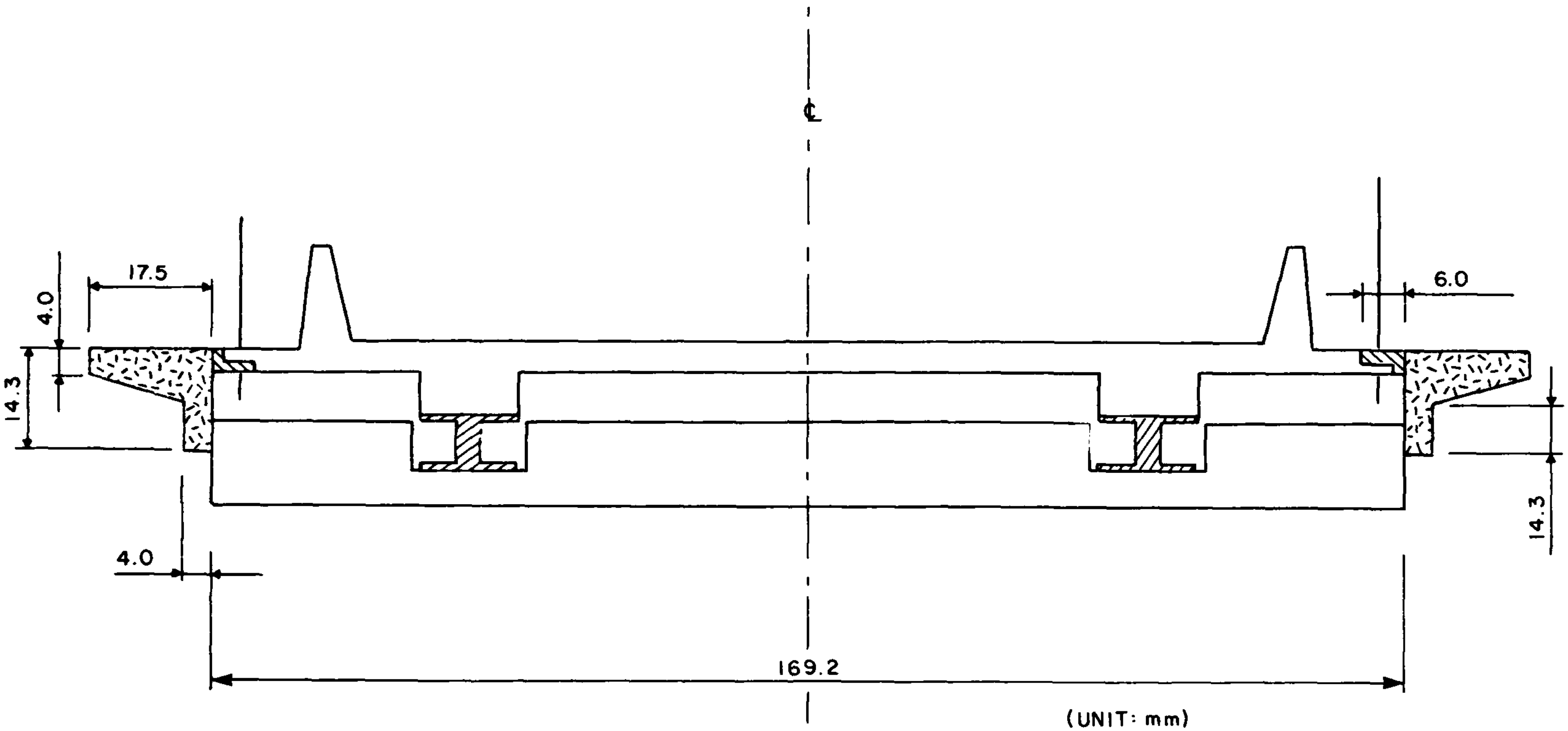
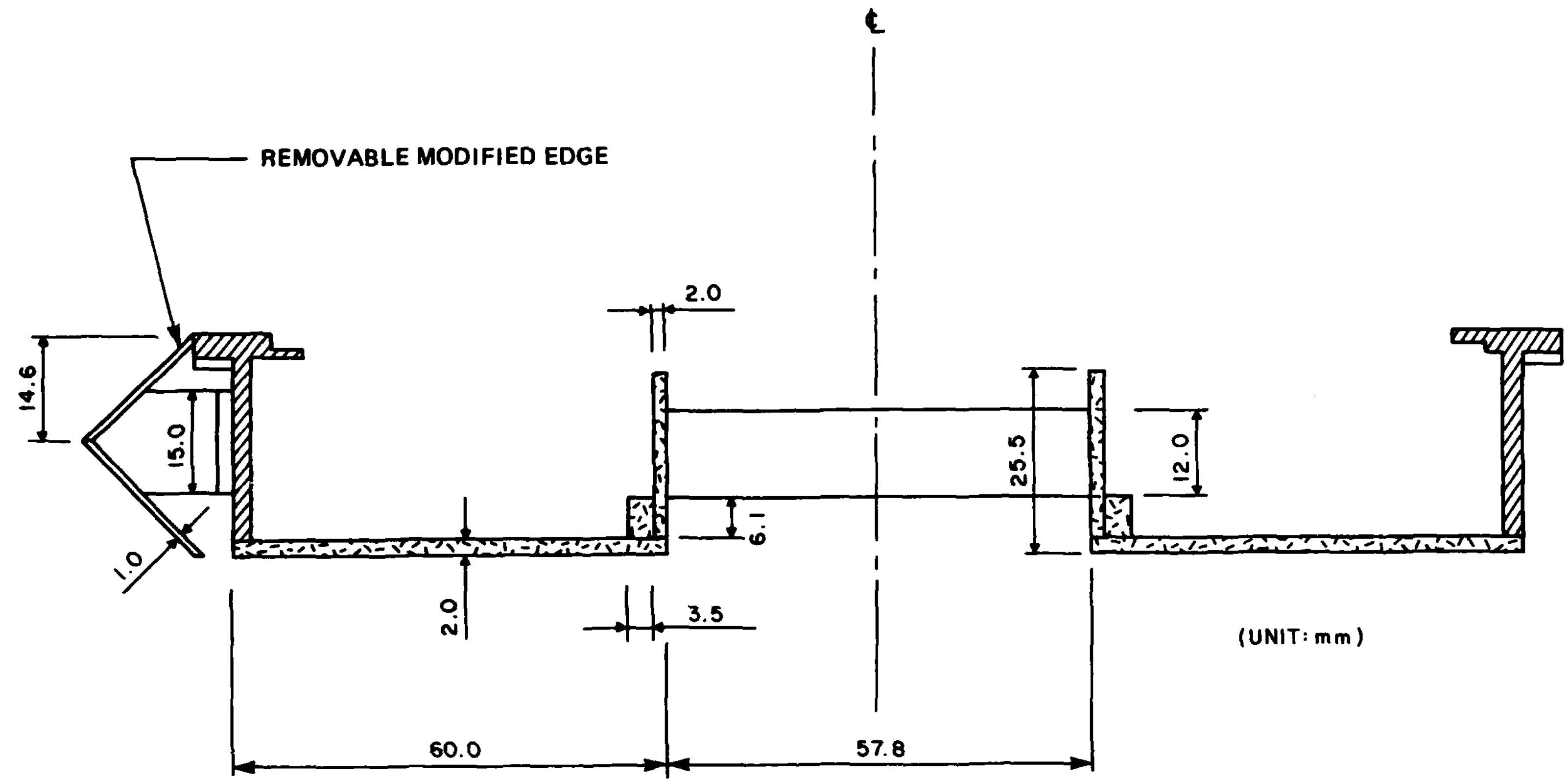


FIG. 8: TYPICAL FRAMING PLAN, QUINCY MODELS



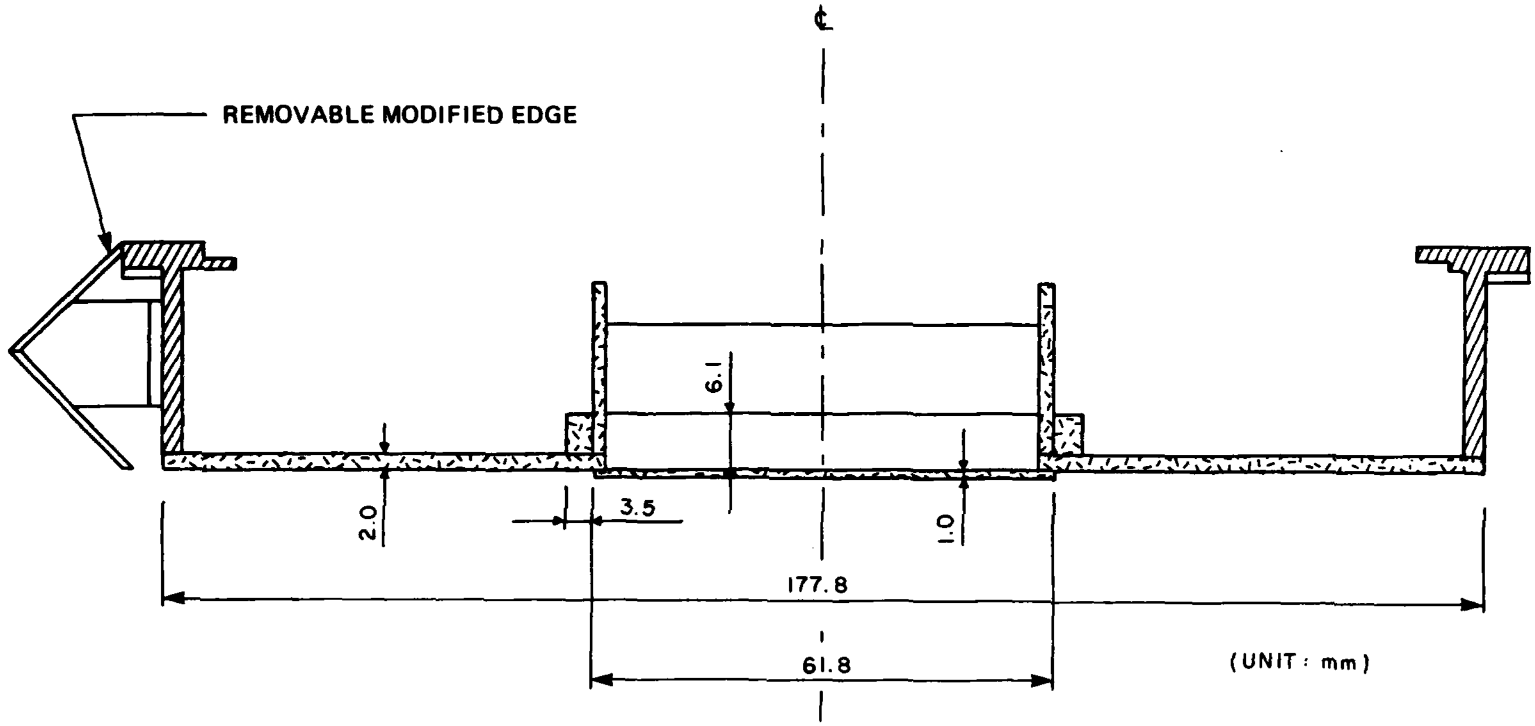
OTHER DIMENSIONS ARE THE SAME AS BRIDGE DECK SYSTEM

FIG. 9: COMPOSITE GIRDER SECTION



OTHER DIMENSIONS ARE THE SAME AS QUINCY SECTIONS

FIG. 10: INSERT FOR TWIN-BOX SECTION



OTHER DIMENSIONS ARE THE SAME AS TWO-BOX SECTION

FIG. 11: INSERT FOR SINGLE-BOX SECTION

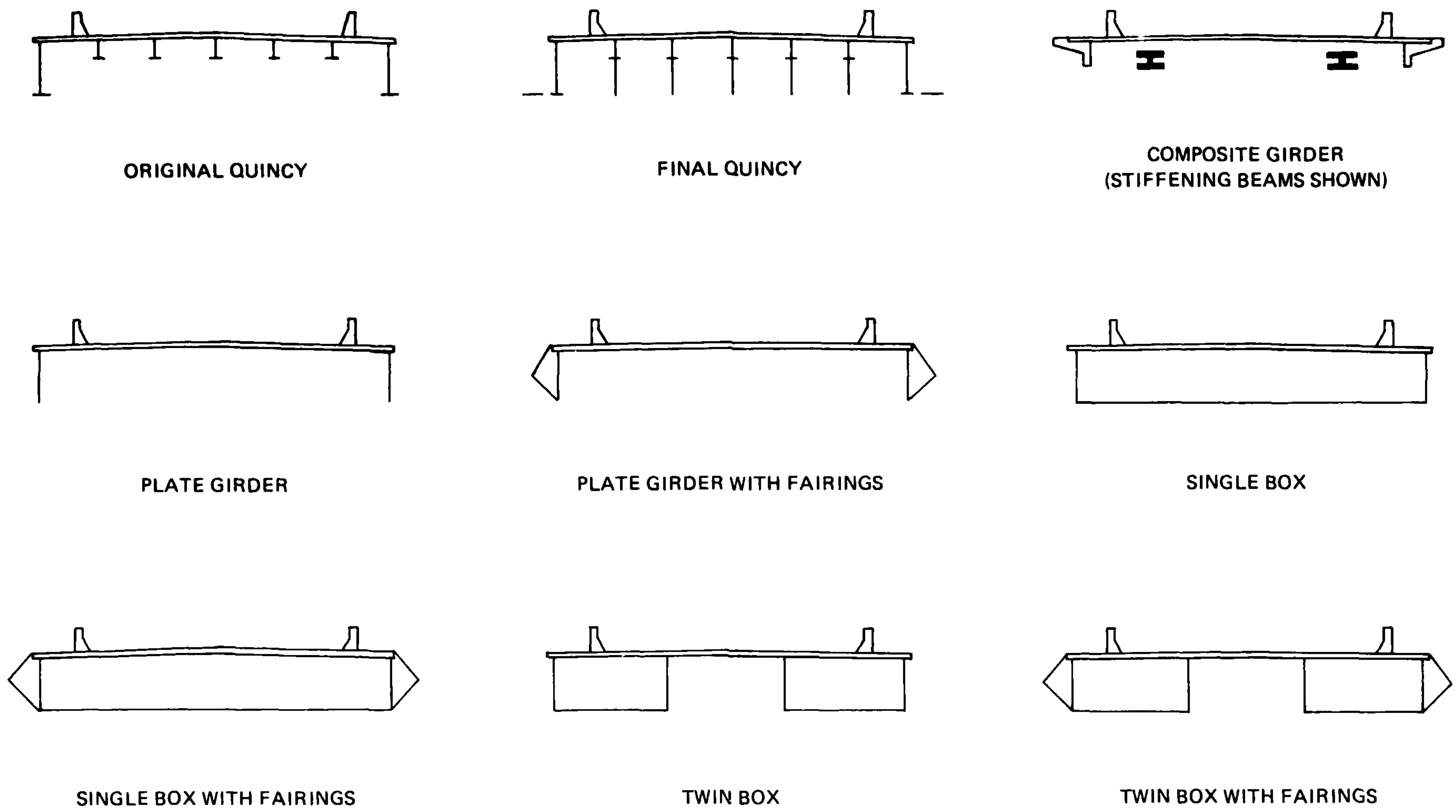


FIG. 11(a): DECK CONFIGURATIONS

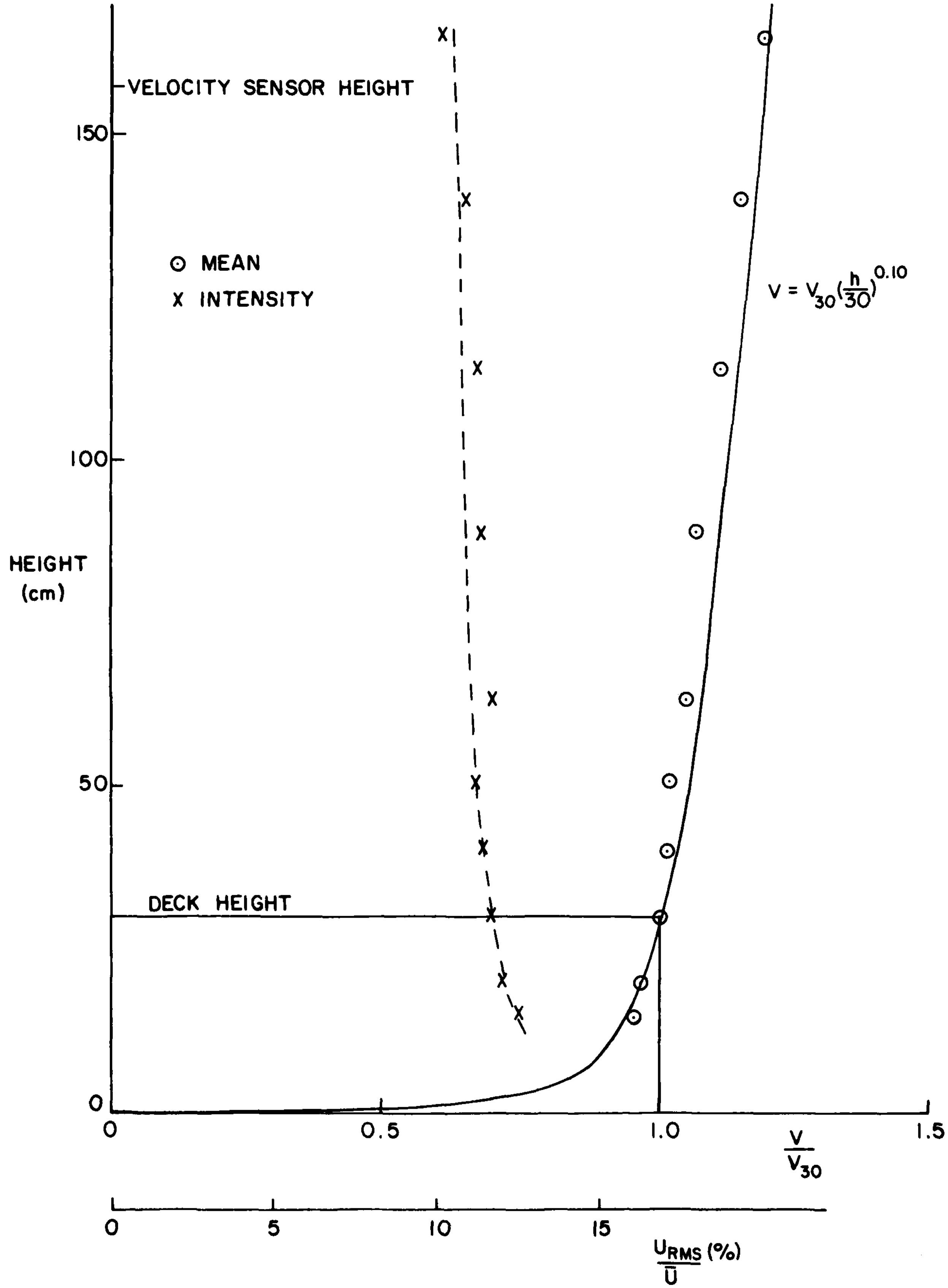


FIG. 12: VARIATION OF MEAN WIND SPEED AND TURBULENCE INTENSITY WITH HEIGHT
SPIRE SIMULATION

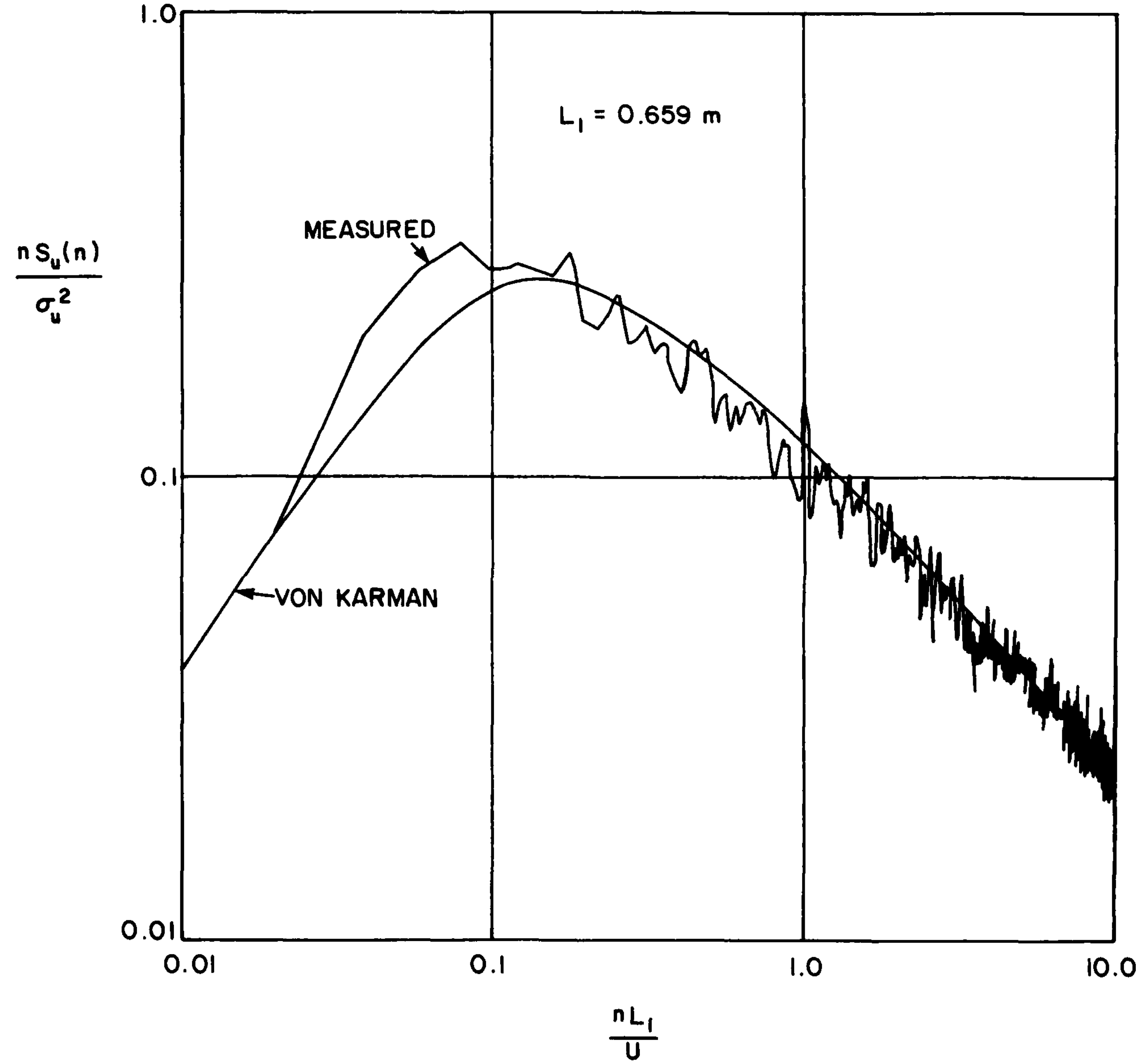


FIG. 13: U-SPECTRUM SPIRE SIMULATION

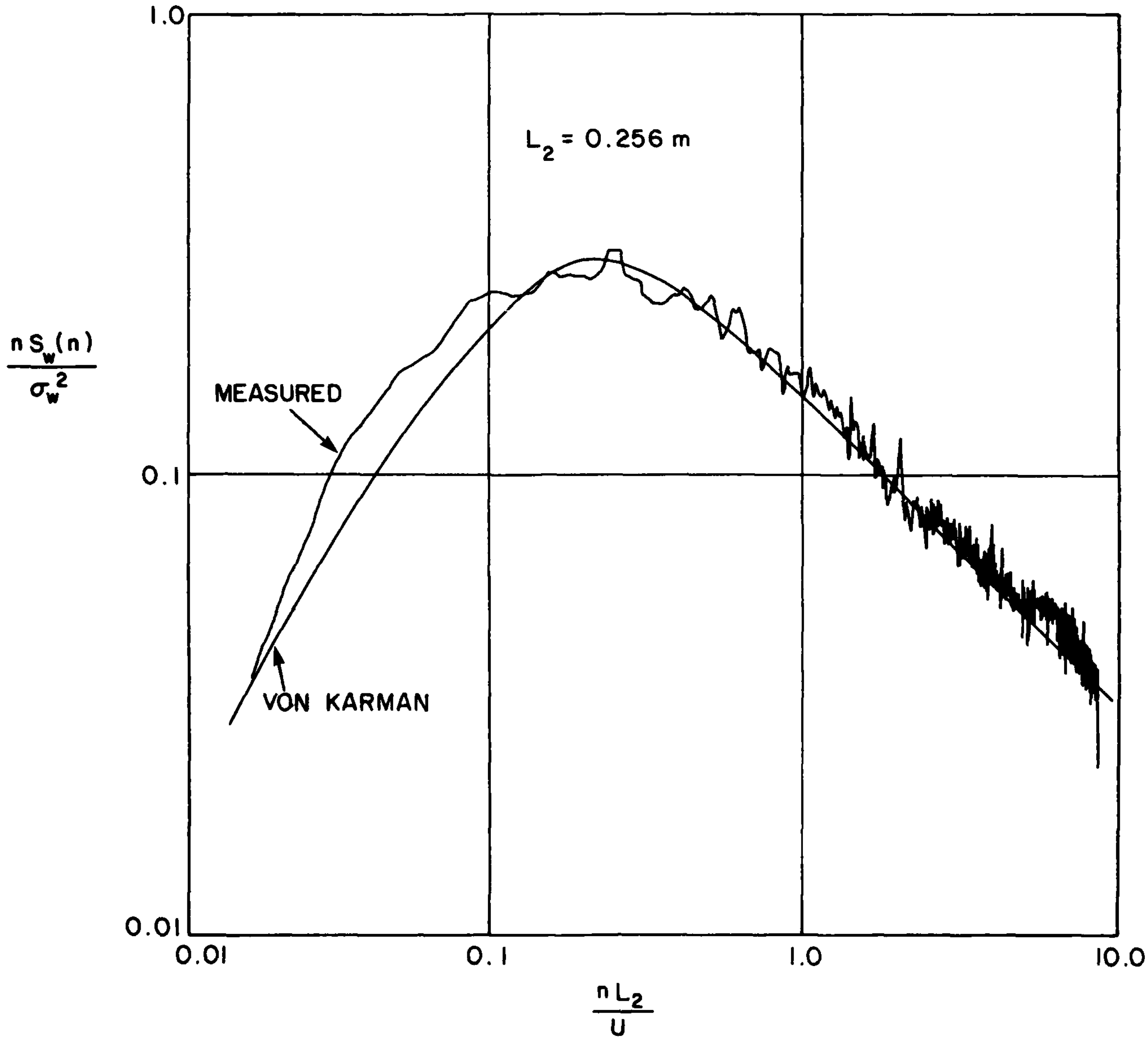


FIG. 14: W-SPECTRUM SPIRE SIMULATION

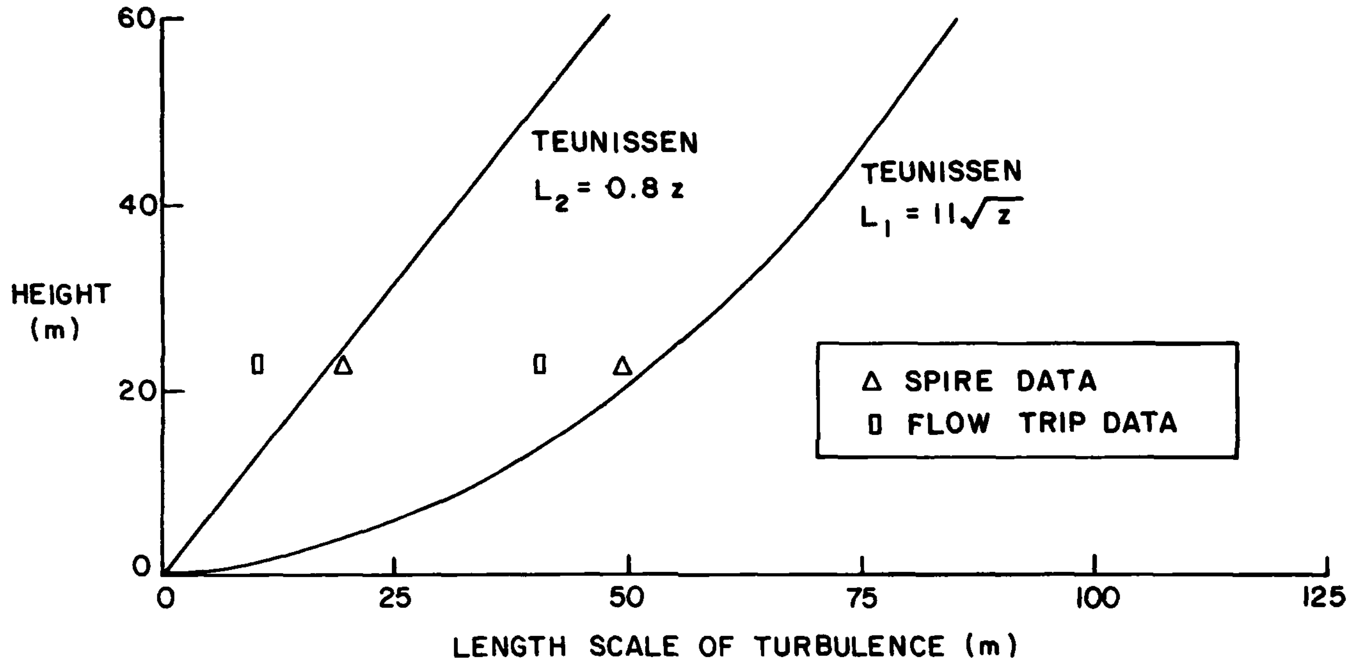


FIG. 15: COMPARISON OF LENGTH SCALES WITH FULL SCALE DATA

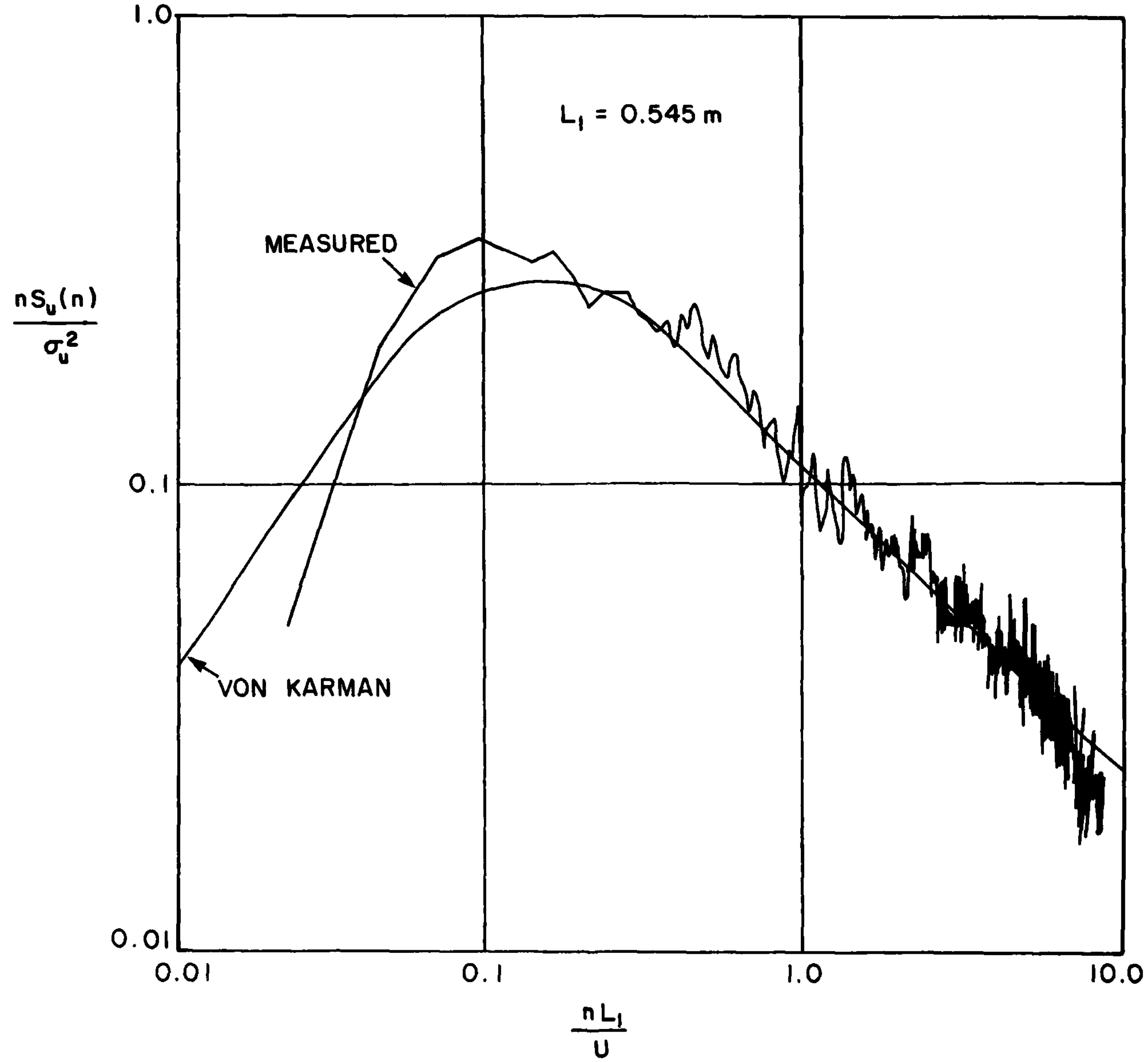


FIG. 16: U-SPECTRUM FLOW TRIP SIMULATION

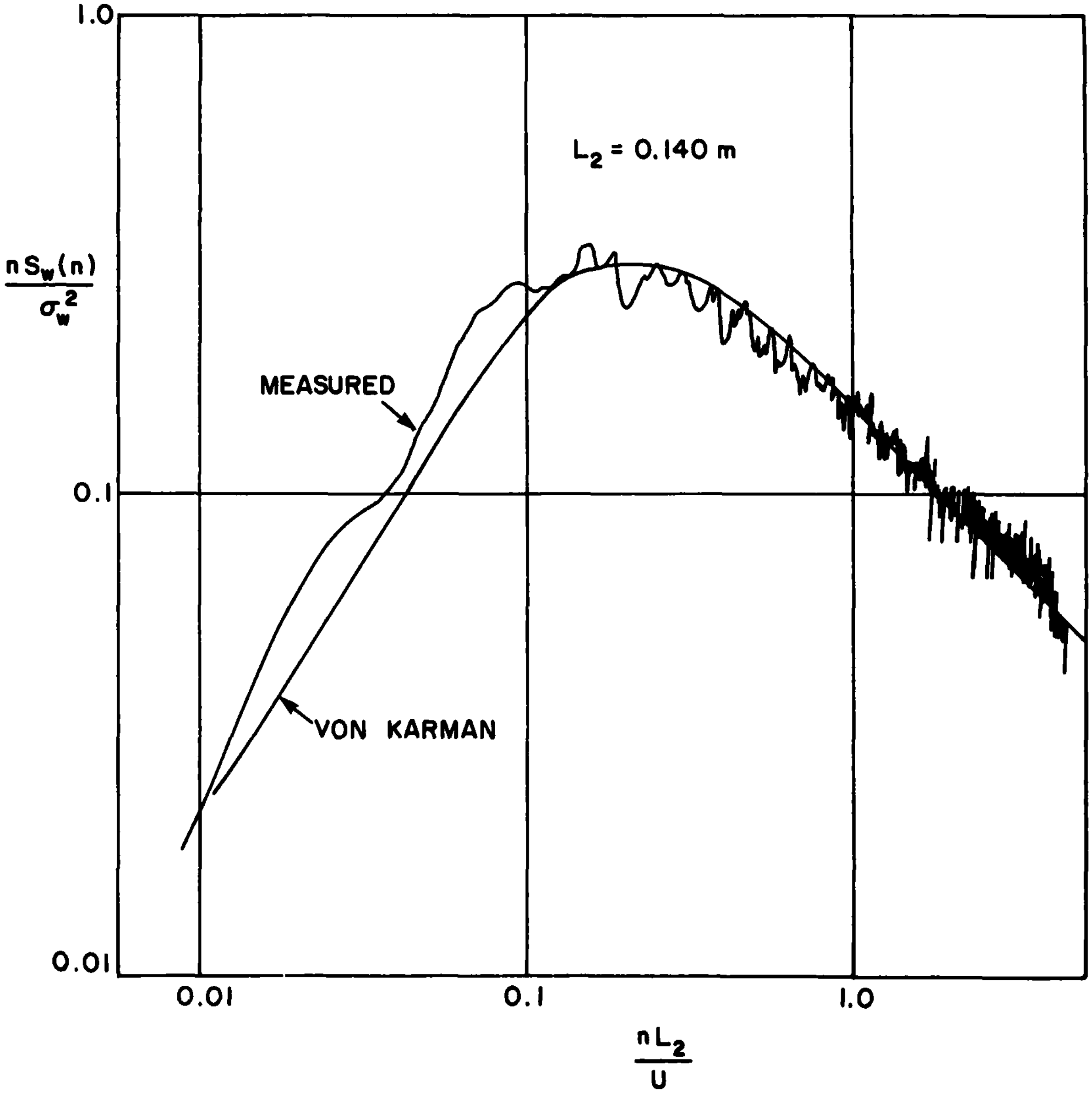


FIG. 17: W-SPECTRUM FLOW TRIP SIMULATION

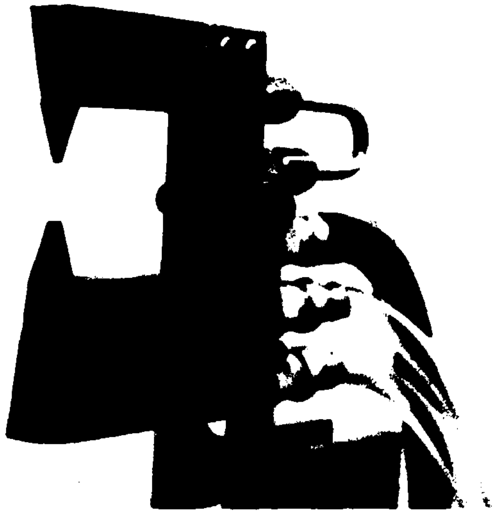


FIG. 18: FLUIDIC CROSS-FLOW VELOCITY SENSOR

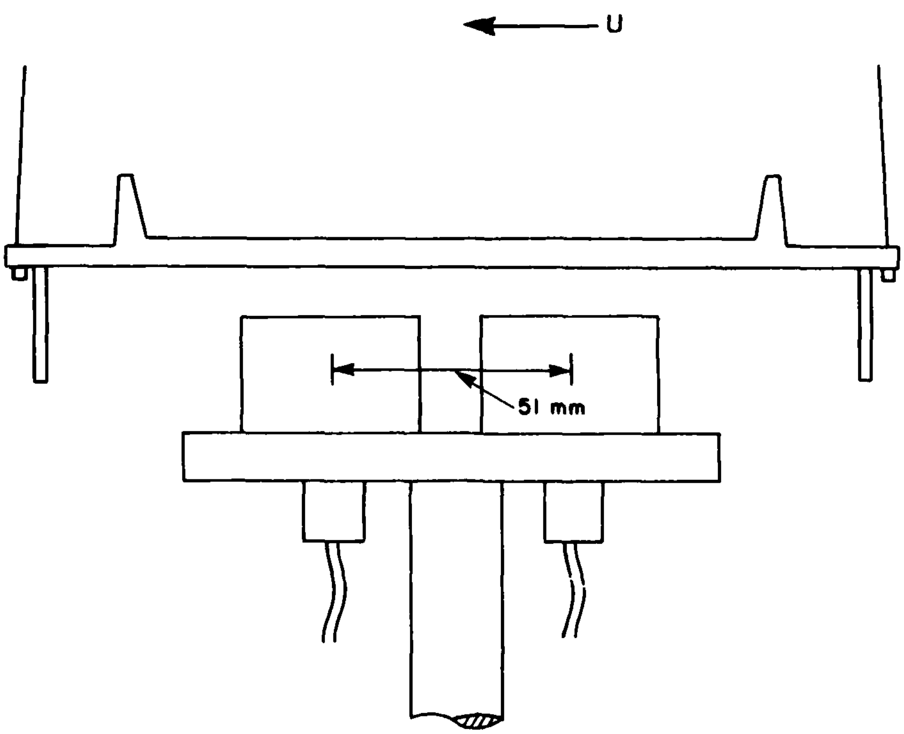


FIG. 19: TRANSDUCER POSITIONS

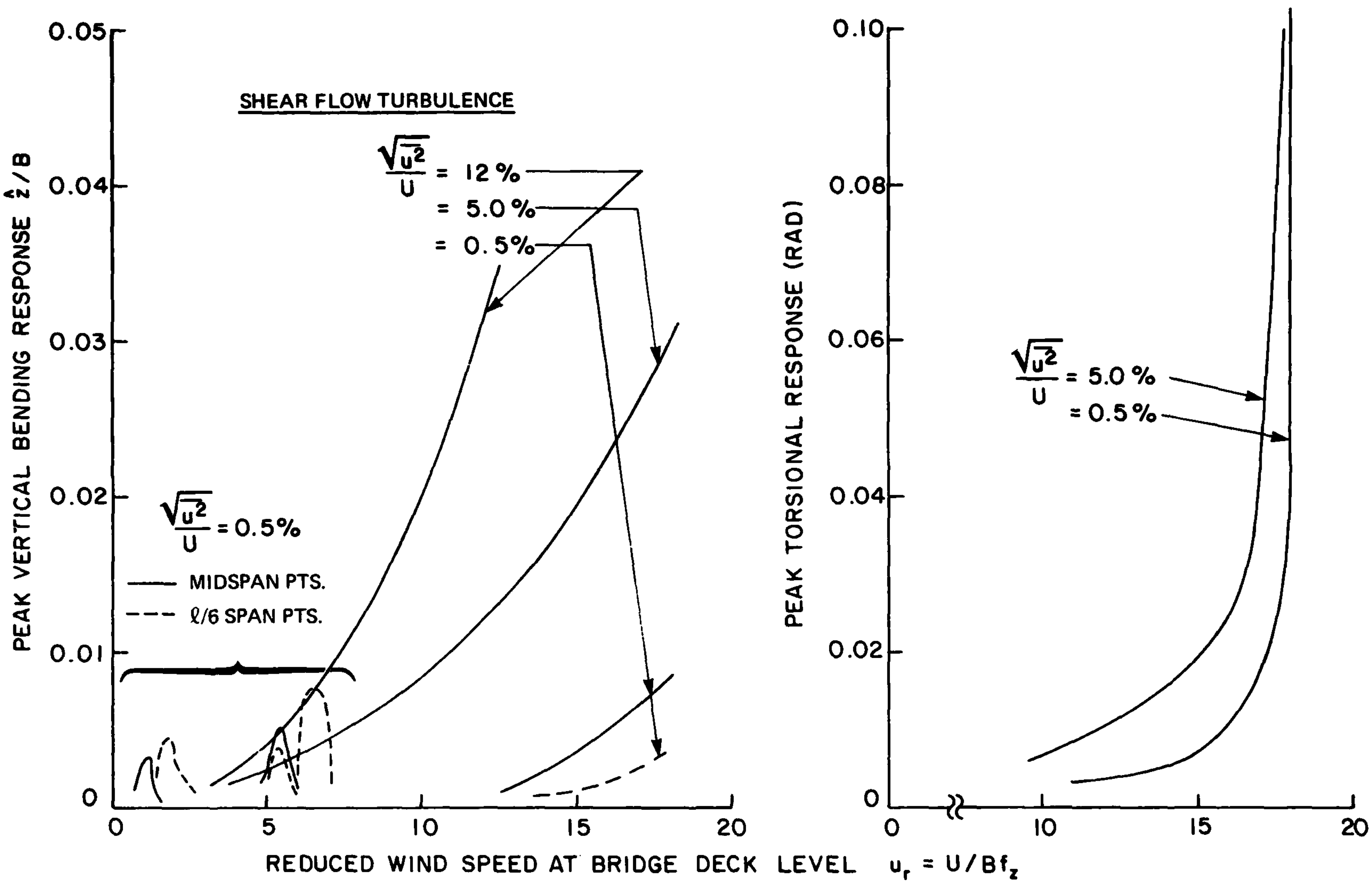


FIG. 20: QUINCY BRIDGE ORIGINAL SECTION

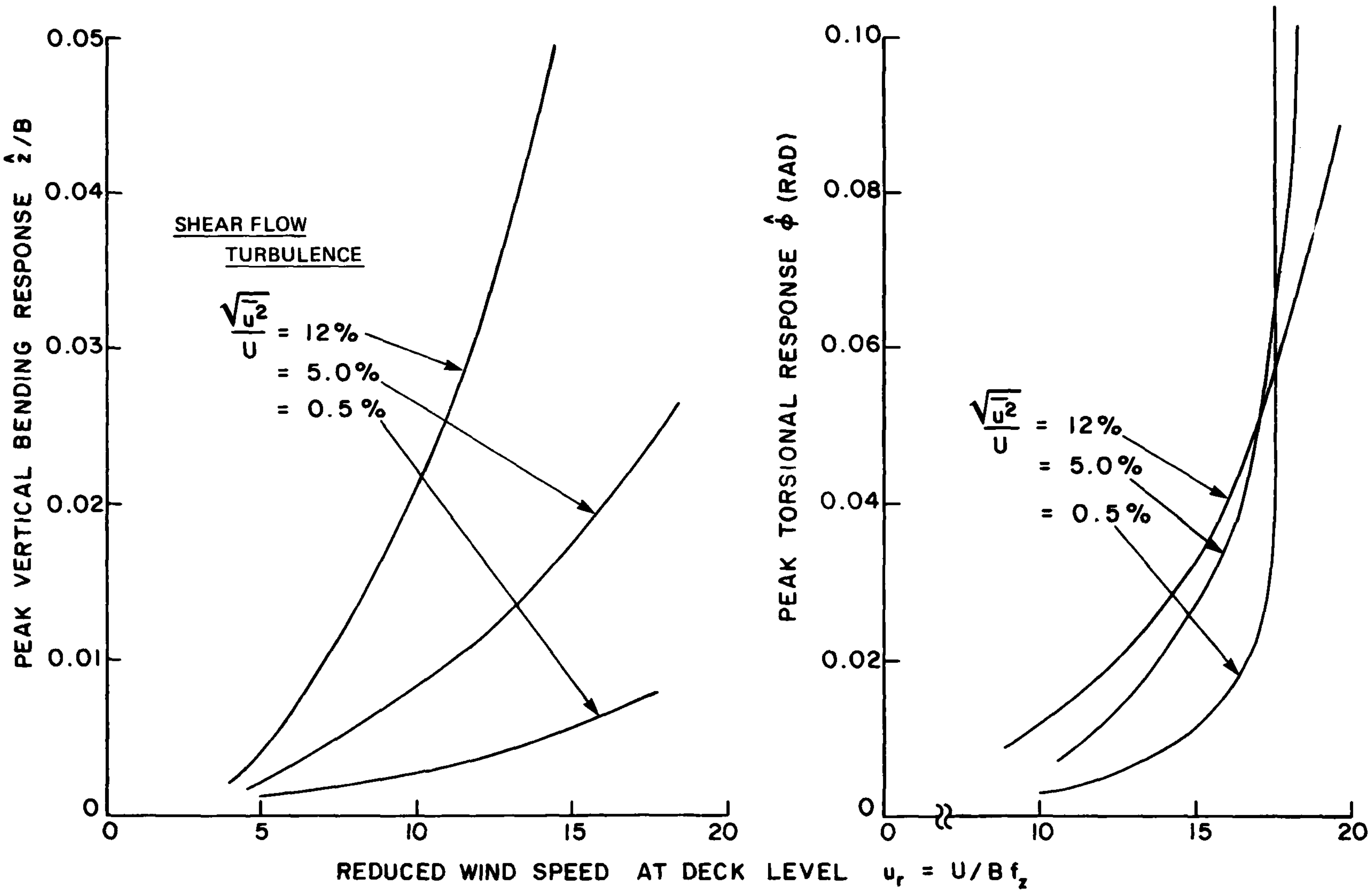


FIG. 21: QUINCY BRIDGE FINAL SECTION

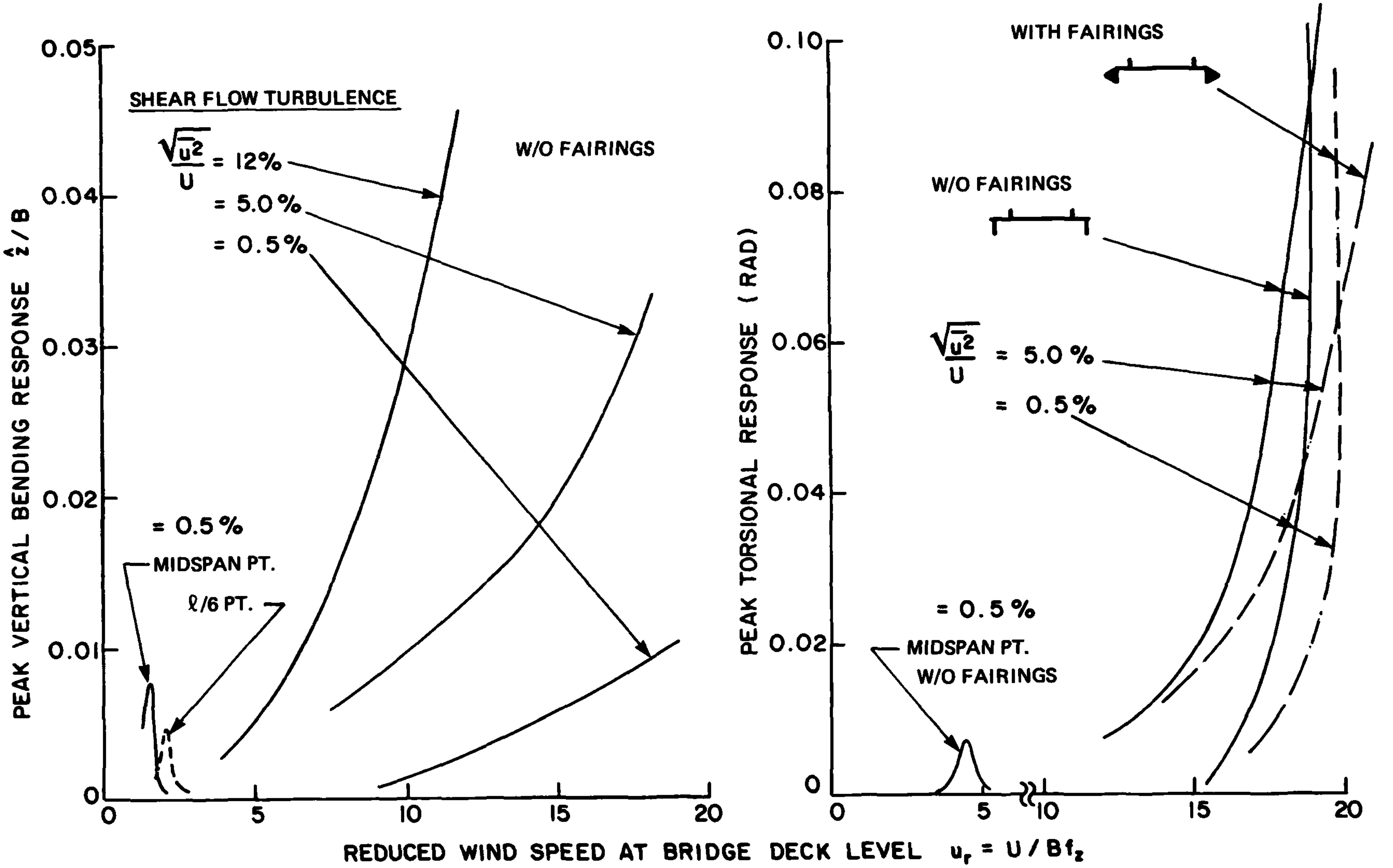


FIG. 22: PLATE GIRDER SECTION

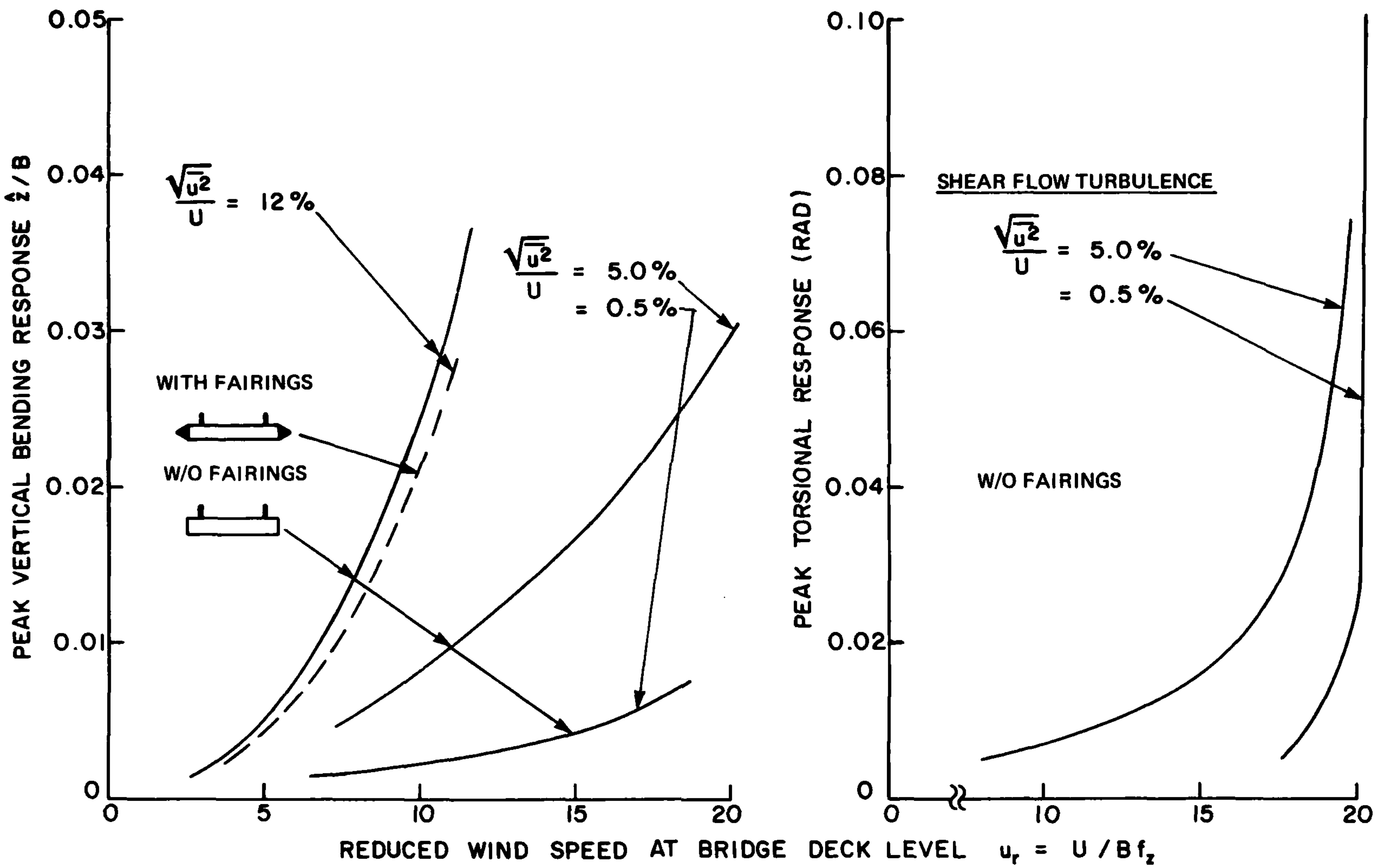


FIG. 23: SINGLE-BOX SECTION

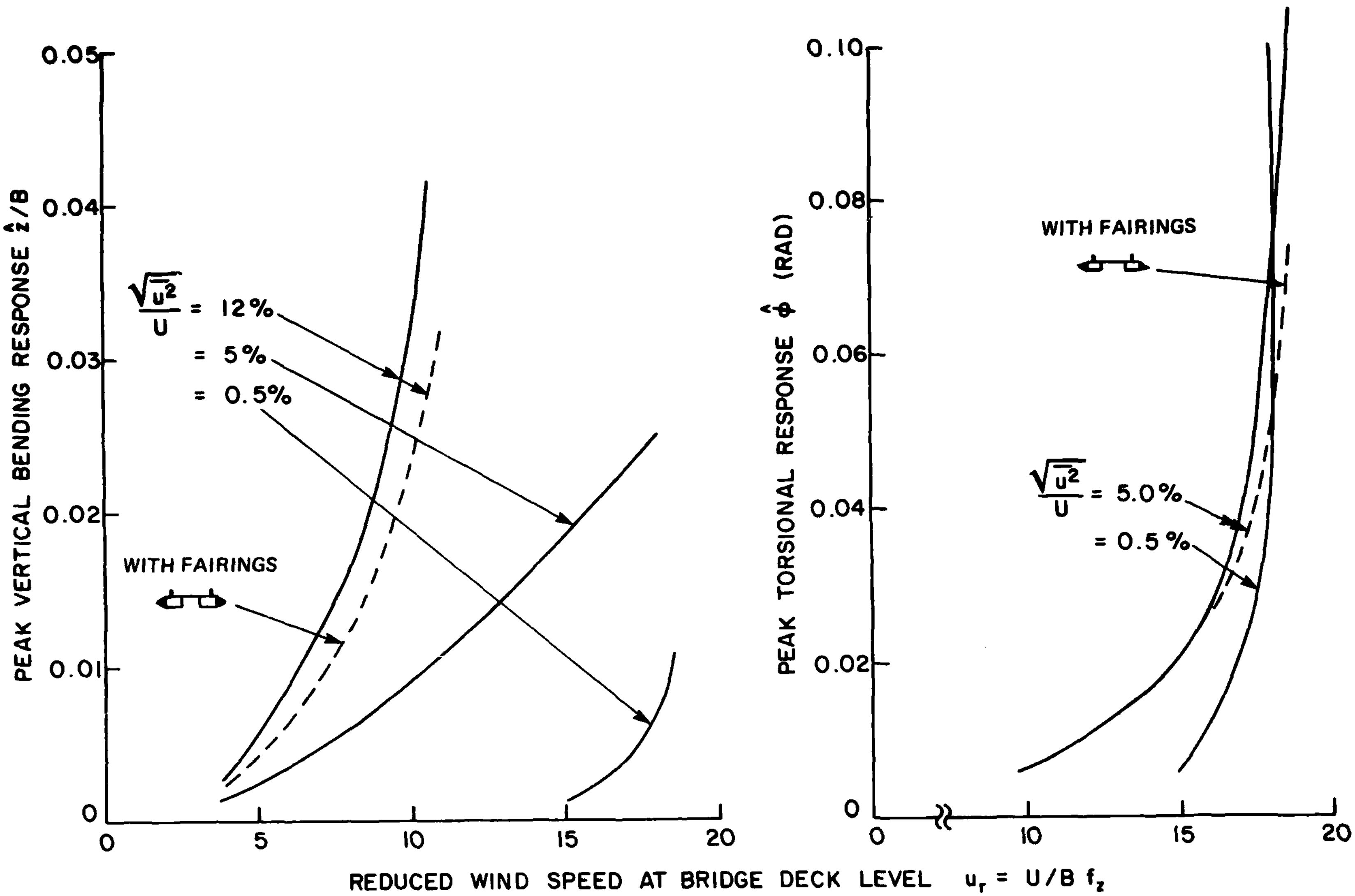


FIG. 24: TWIN-BOX SECTION

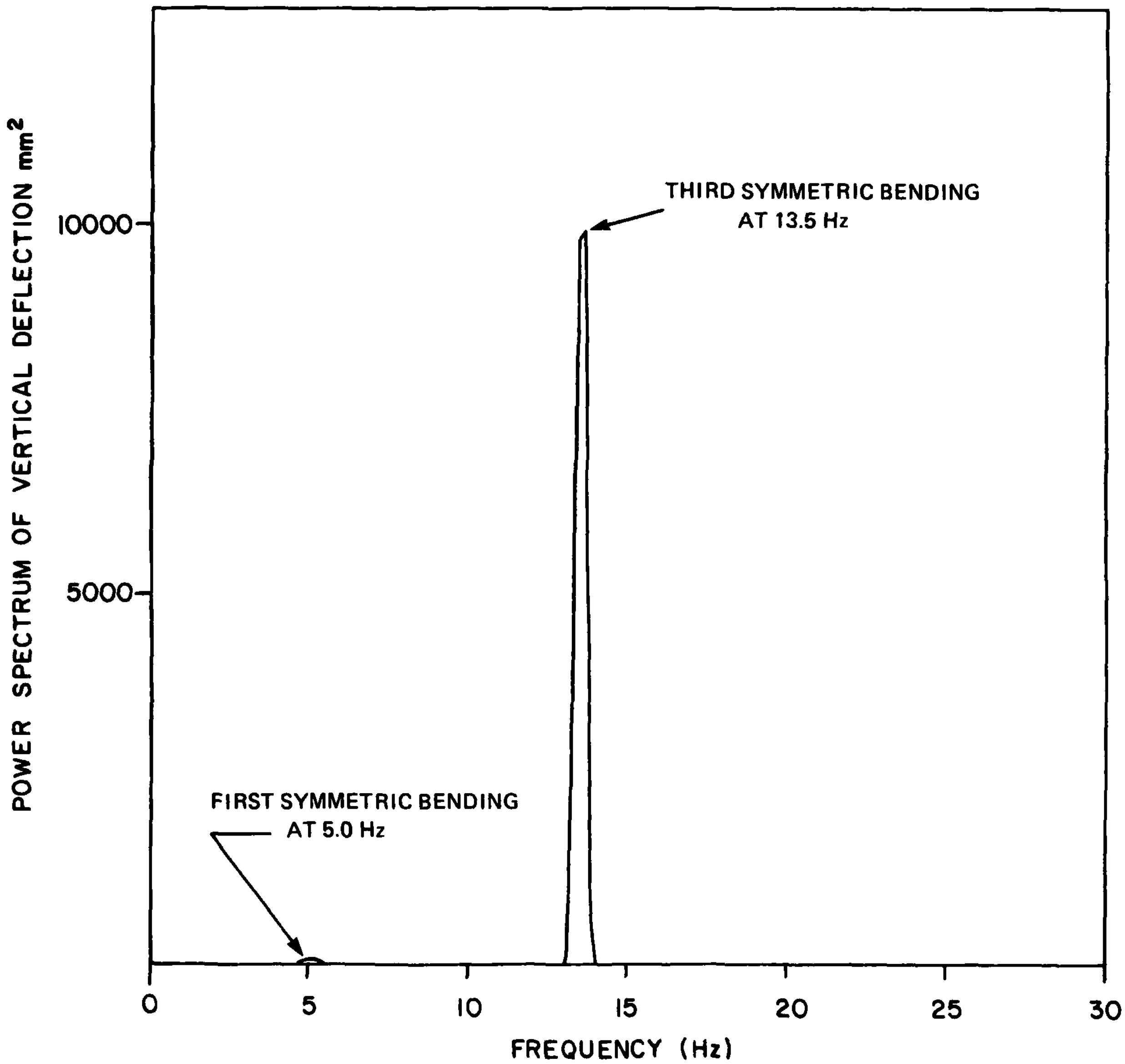


FIG. 25: POWER SPECTRUM OF VERTICAL DEFLECTION SHOWING RESPONSE OF BRIDGE TO VORTEX SHEDDING IN THIRD SYMMETRIC MODE

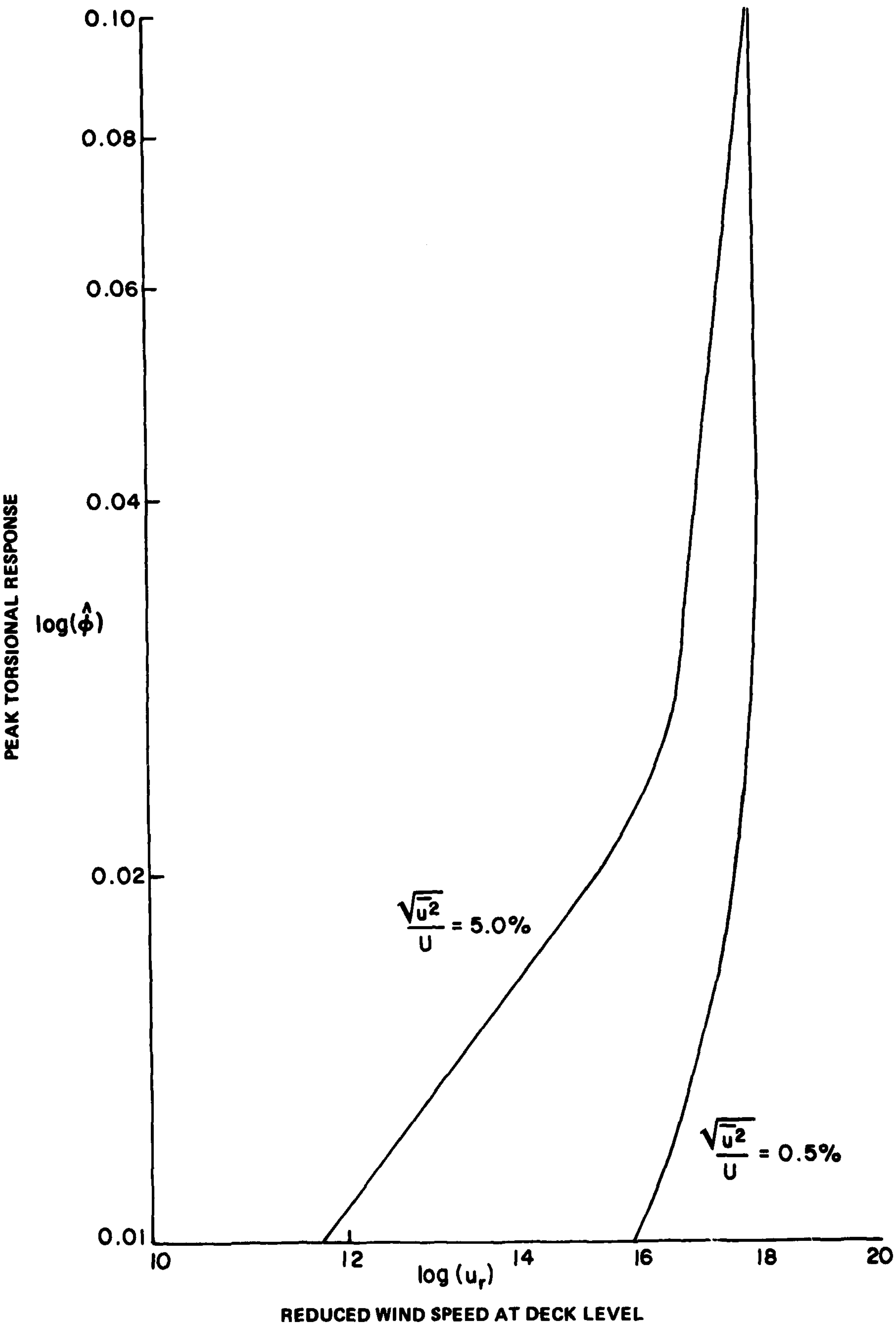


FIG. 26: QUINCY BRIDGE ORIGINAL SECTION TORSIONAL RESPONSE

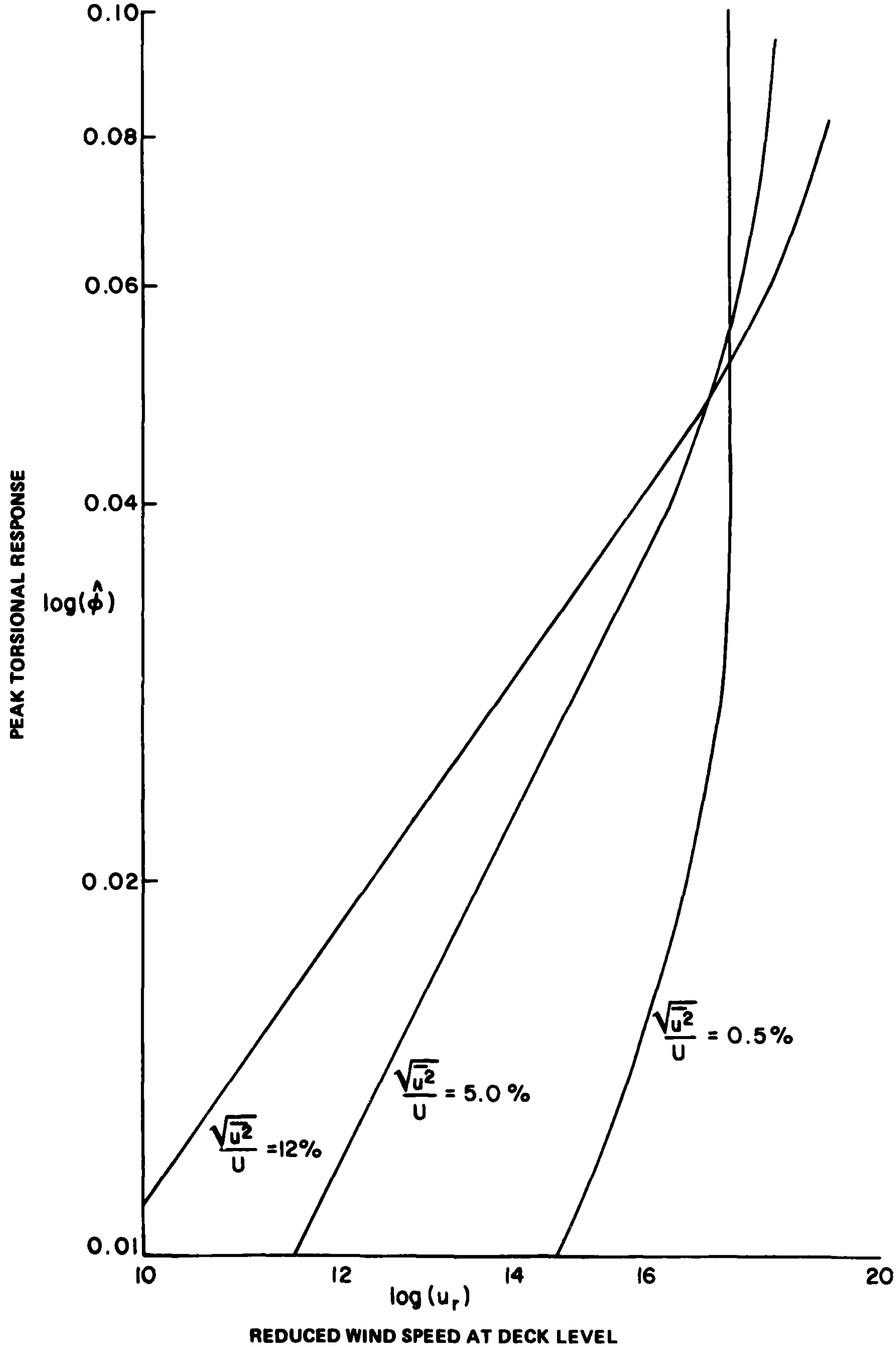


FIG. 27: QUINCY BRIDGE FINAL SECTION TORSIONAL RESPONSE

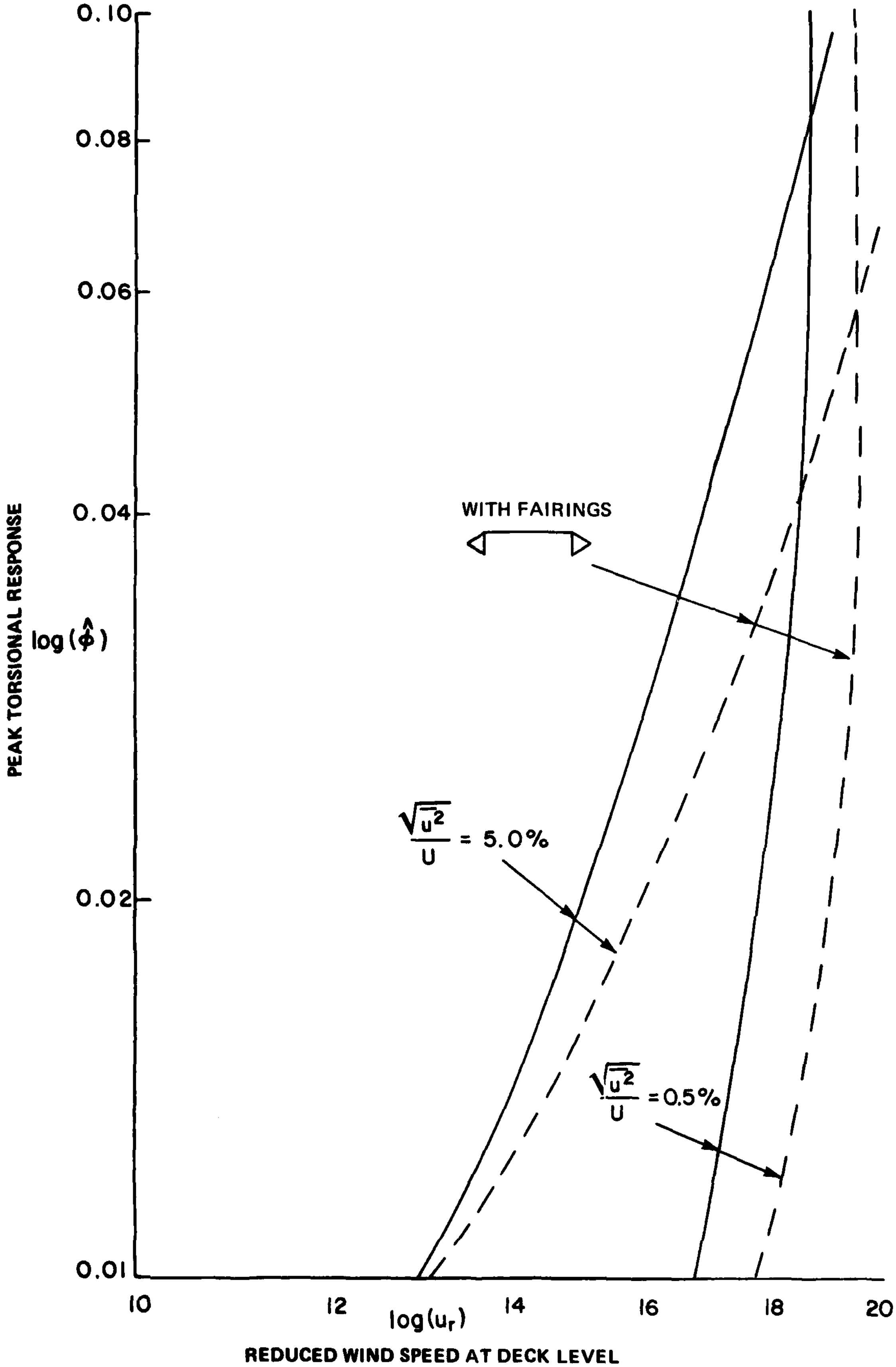


FIG. 28: PLATE GIRDER SECTION TORSIONAL RESPONSE

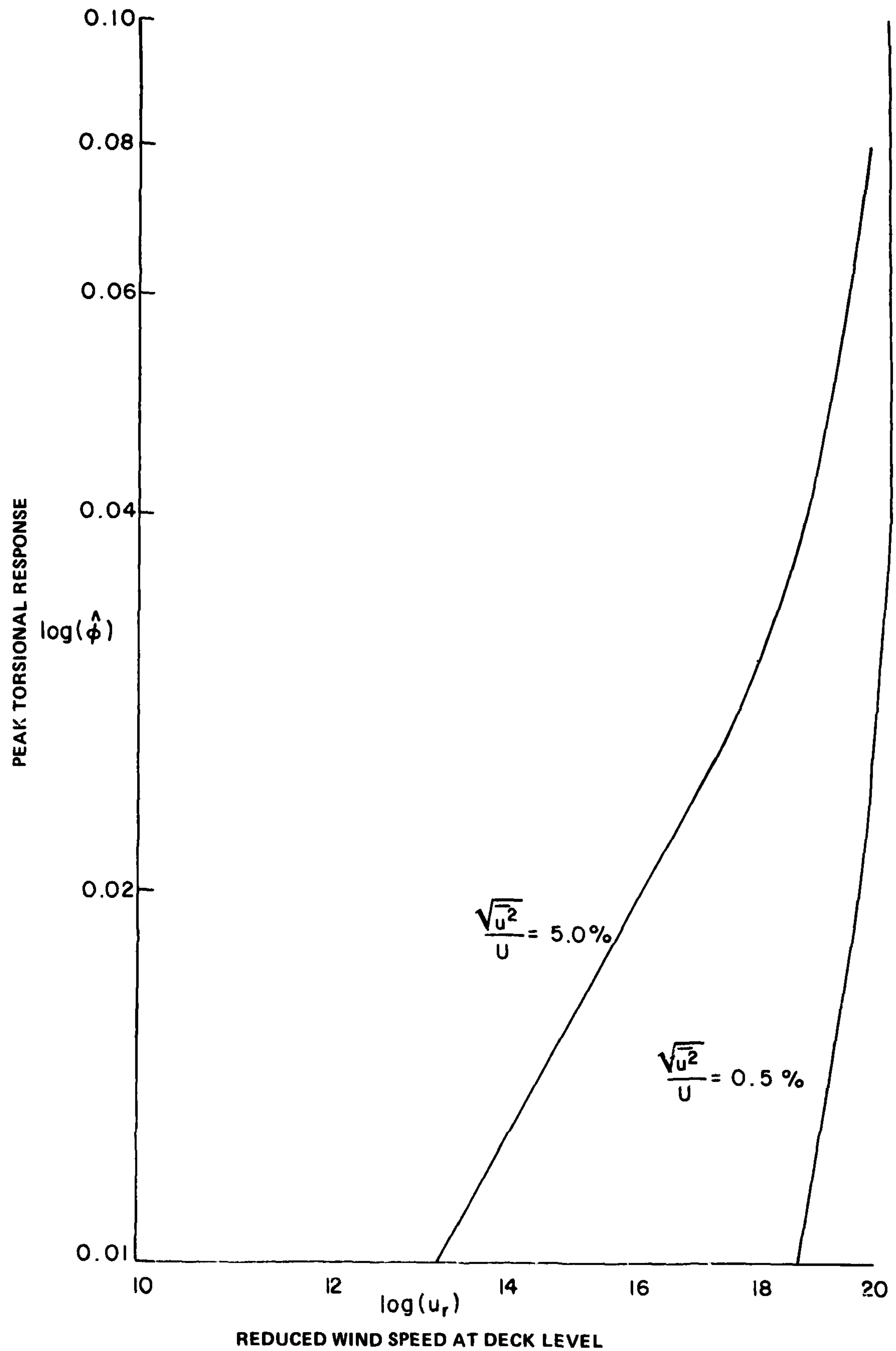


FIG. 29: SINGLE-BOX SECTION TORSIONAL RESPONSE

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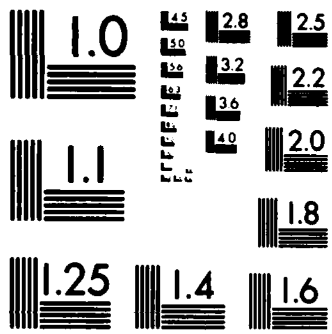

1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

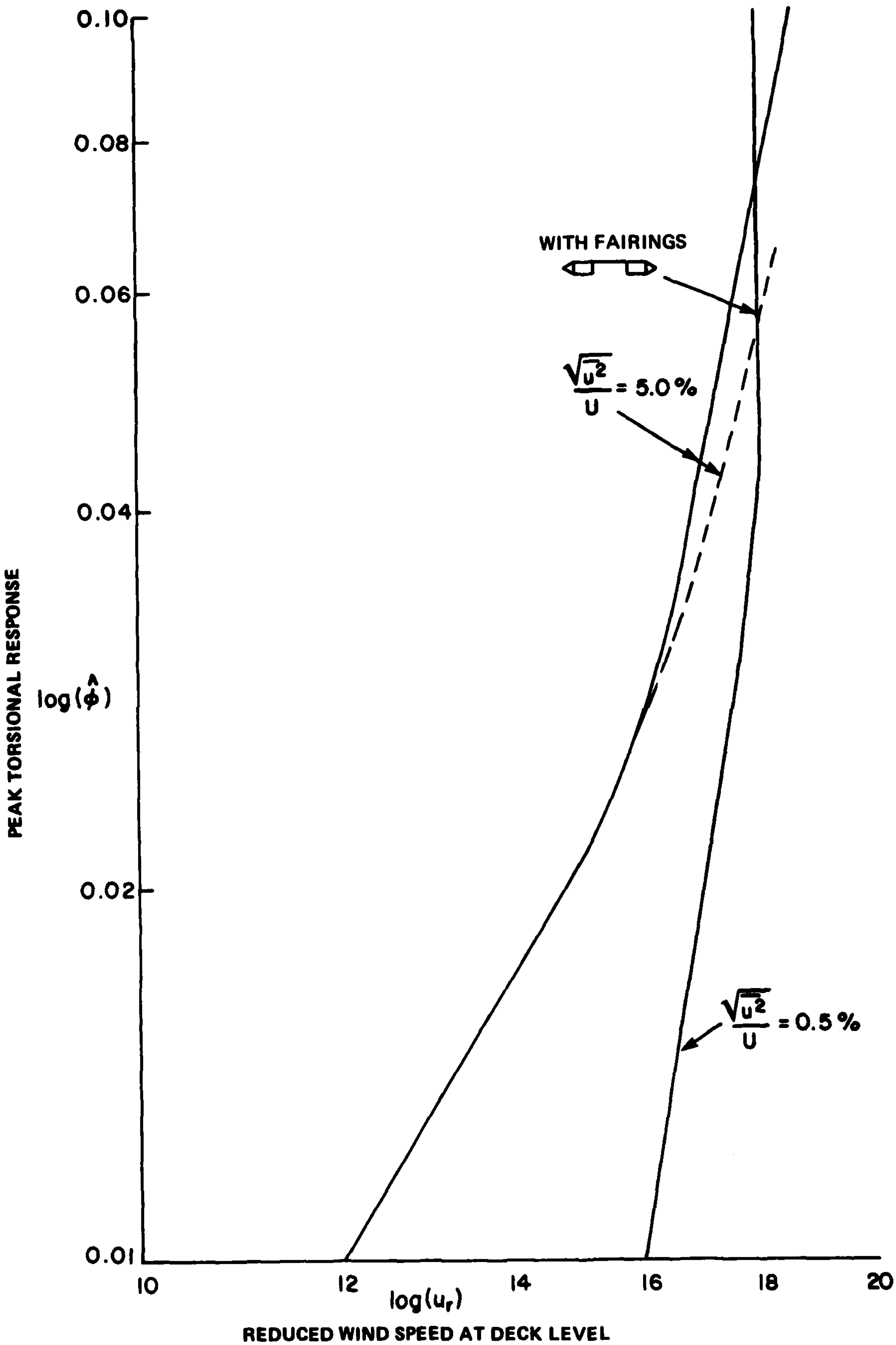


FIG. 30: TWIN-BOX SECTION TORSIONAL RESPONSE

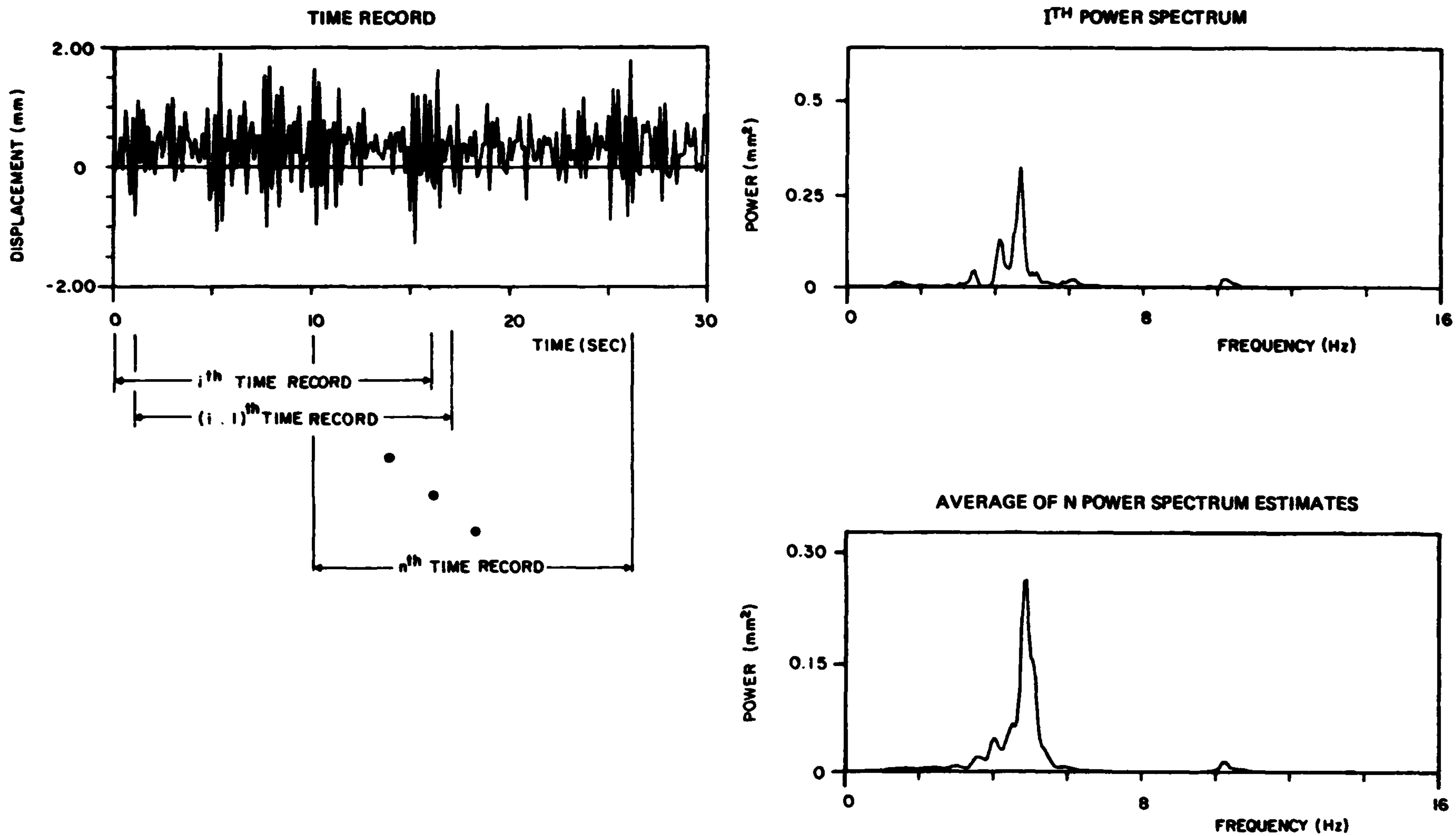


FIG. B1: SPECTRAL AVERAGING TECHNIQUE

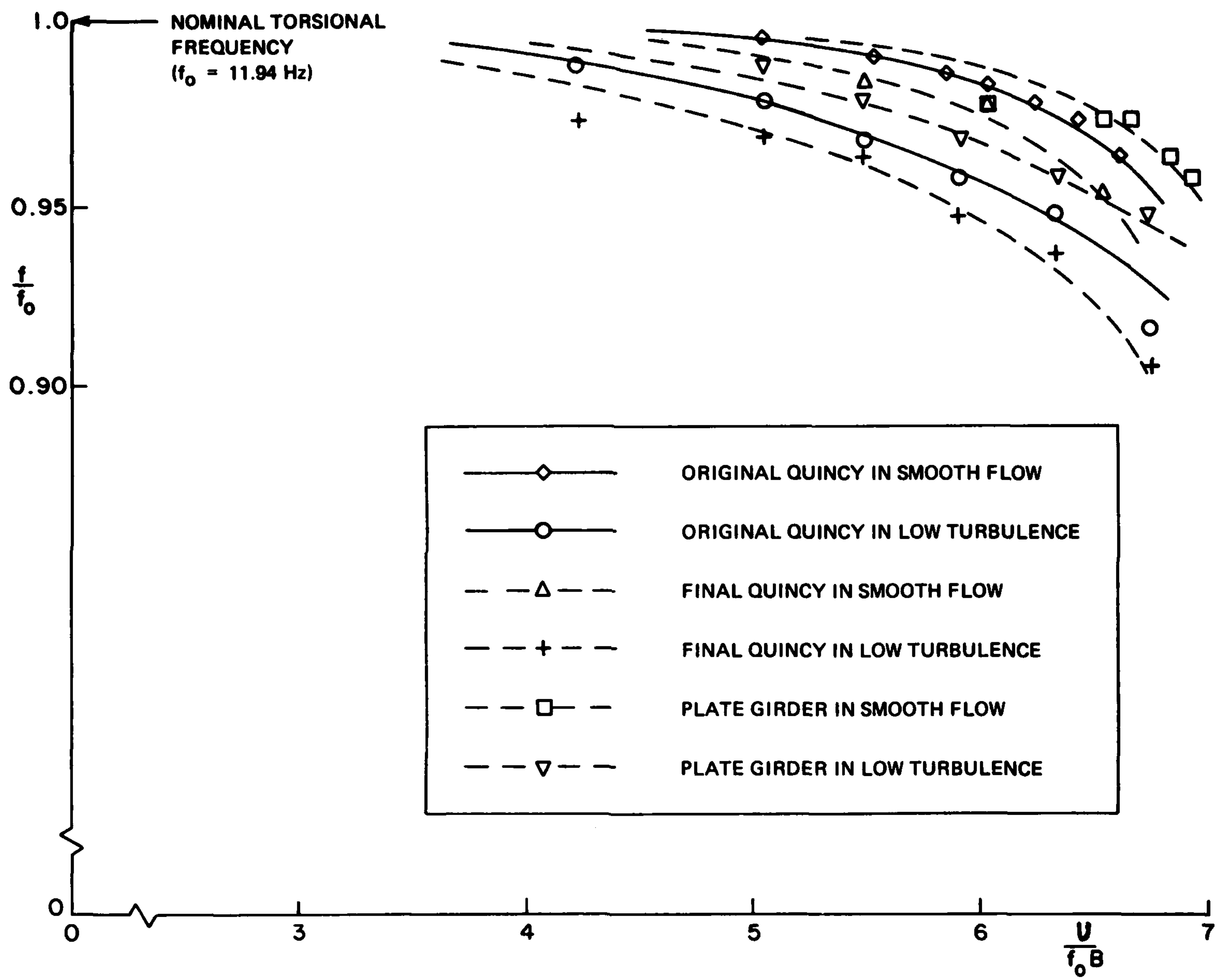
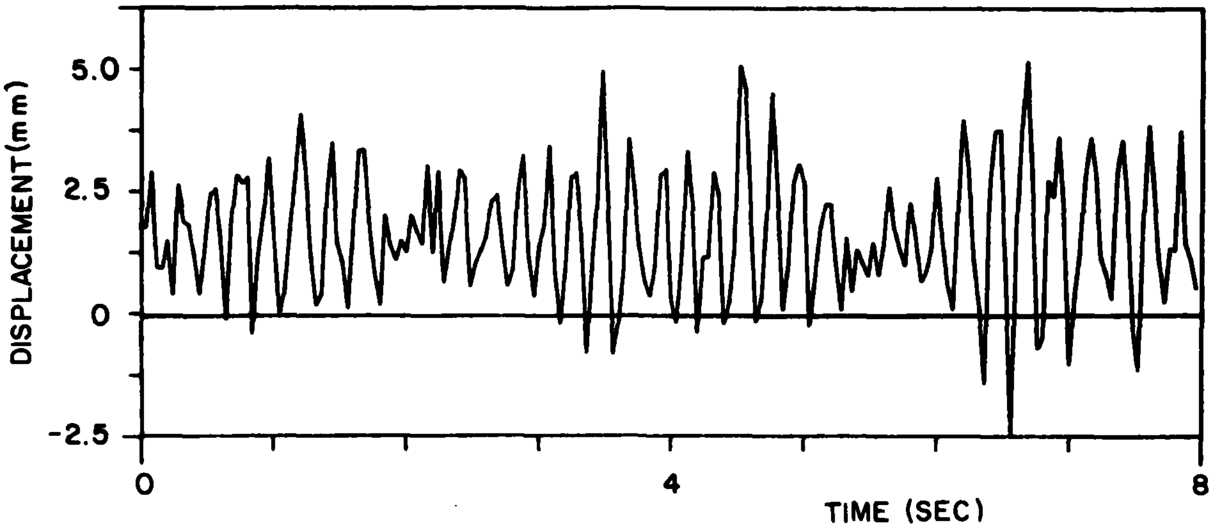


FIG. B2: DEPENDENCE OF TORSIONAL FREQUENCY ON WINDSPEED AT HIGH REDUCED VELOCITY



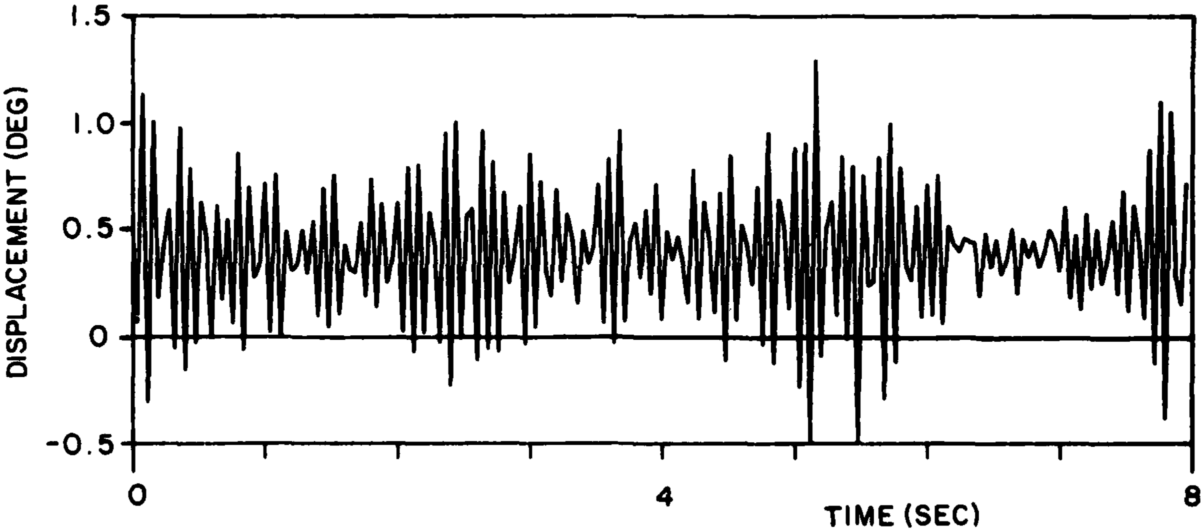


FIG. B3: COMPETITION BETWEEN MODES IN SLIGHTLY TURBULENT FLOW SINGLE-BOX SECTION

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4

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SERIES/SÉRIE

Aeronautical Note

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DESCRIPTORS (KEY WORDS)/MOTS-CLÉS

BRIDGES, WIND EFFECTS, VORTEX SHEDDING, FLUTTER, BUFFETING, TURBULENCE, WIND TUNNEL TESTING

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SUMMARY/SOMMAIRE

This report contains the results of a full aeroelastic model test of a cable-stayed bridge at a geometric scale of 1:75. Nine deck section configurations were tested in three different flows; two of which were properly scaled atmospheric turbulence, and the third being smooth flow. The experiments were performed in the 9 m x 9 m wind tunnel of the National Aeronautical Establishment.

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